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VOL. XXXIII.

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OBITUARY NOTICES OF FELLOWS DECEASED.

JAMES CLERK MAXWELL was born in Edinburgh, on the 13th of June, 1831. His father, who was brother to Sir George Clerk, of Pennicuick, was at first known as John Clerk, but adopted the name of Maxwell on succeeding to an estate called Nether Corsock, which had come into the Clerk family through the marriage of a Miss Maxwell. To this estate he added, by purchase, that of Glenlair, the name of which became afterwards closely associated with that of his son.

James Clerk Maxwell's boyhood did not at first give much promise of distinction. He was a quiet and not very sprightly child, though much given to reading, drawing pictures chiefly of animals, and constructing geometrical models. At the Edinburgh Academy to which he was sent, he took no leading position among his school-fellows till about the age of thirteen, when his mental faculties began to develop rapidly, so that he was soon in every department among the foremost of his contemporaries. At this school he made the acquaintance of Professor Tait, the present occupant of the Chair of Natural Philosophy in Edinburgh University; an acquaintance which, cemented as it was by kindred pursuits and interests, ripened into a close and lasting friendship.

From the Academy he passed to the University of Edinburgh, where, in 1847, he attended the lectures of Kelland and Forbes. For the next two or three years he had the privilege, to him invaluable, of using the class apparatus in private experiments. What was the nature of some of those experiments we may conjecture from a perusal of his paper on Elastic Solids, written during this time, in which he describes some experiments made with the view of verifying the deductions of his theory in its applications to optics.

This paper was read to the Royal Society of Edinburgh on February 18, 1850, and cannot but be regarded as a wonderful production when we consider the age of its author. This was the third paper which Maxwell had addressed to the same Society: the first, "On the Description of Oval Curves and those having a Plurality of Foci," was read for him by Forbes in 1846; the second, under the title "The Theory of Rolling Curves," was presented by Kelland in 1849. All these papers, therefore, were written before he came into residence as an undergraduate at Cambridge in October, 1850.

While an undergraduate at Cambridge, Maxwell carried on his studies in a leisurely manner without producing, or at least without publishing, any original work. He became in due course a scholar of the College. He was also elected member of a literary club, coming thereby in contact with some of the most accomplished of his contemporaries.

In January, 1854, he took the degree of B.A., being Second Wrangler, but equal with the Senior Wrangler in the subsequent examination for the Smith's Prizes.

Shortly after taking his degree, he produced a memoir "On the Transformation of Surfaces by Bending." By bending a surface is meant "a continuous change of the form of the surface without extension or contraction of any part of it," and the problem Maxwell set himself was to discover some method at once simple and general in its application for the measurement of the change in question. Besides its main purpose, which was to develop clearer ideas of the theory of bending, there are incidentally scattered through it good expositions of many points in the geometry of surfaces, as, for instance, the discussions on curvature and the deduction of Gauss's and other expressions for specific curvature.

Up to this point we have directed attention to Maxwell's papers in the order in which they were published, there being a special interest attaching to them on account of the very early period of life at which they were written. It will be convenient, however, to consider his published papers under some sort of classification, and this we propose to do further on; in the meantime the leading events of his life subsequent to 1854 may now be briefly recorded.

In 1855 he was elected to a fellowship at Trinity, which he retained until his marriage in 1858. He was, however, subsequently elected to an honorary fellowship, a distinction which the College confers only upon the most gifted of her sons. The latter honour was shared on the same occasion by Dr. Lightfoot, the present Bishop of Durham, the late Mr. Spedding, editor of Bacon's works, and Professor Cayley.

In 1856 he was appointed Professor of Natural Philosophy in Marischal College, Aberdeen, where he continued till that College was united to her rival, King's College, and formed into what is now known as the University of Aberdeen.

In 1858, he married Katherine Dewar, daughter of the Principal of Marischal College.

During his tenure of the Aberdeen Professorship the subjects which appear to have engaged most of his attention were the Theory of Colours and the Stability of Saturn's Rings, his essay on the latter subject obtaining for him the Adams Prize. He also continued his study of Electricity, and in 1859 we have the first evidence that he was working at the Kinetic Theory of Gases.

In 1860, after the union of the Colleges in Aberdeen, Maxwell obtained the Professorship of Natural Philosophy and Astronomy in King's College, London.

While holding this office he produced some of his most valuable electrical papers, as well as two others on Elasticity. During the same period he took a very prominent part in the experiments organised by a Committee of the British Association for the determination of electrical resistance in absolute measure, and for placing the units of electrical measurements on a satisfactory basis. The experiments were conducted in the Laboratory of King's College upon a plan due to Sir W. Thomson. On this occasion Maxwell worked in conjunction with Professors Balfour Stewart and Fleeming Jenkin, and the results were contained in a report to the British Association in 1863.

Maxwell continued in London until his father's death in 1865, when he determined to reside on the Scotch estates to which he had succeeded, and resigned his professorship.

For some years after this he led a quiet life at Glenlair, devoting himself chiefly, we may conjecture, to the composition of his Treatises on Heat and on Electricity and Magnetism. The most important memoirs from his pen about this period were on the Dynamical Theory of Gases, read to the Royal Society in 1866.

In 1871 he was elected to the newly-created chair of Experimental Physics in the University of Cambridge. His first duties were to plan and superintend the building of the Cavendish Laboratory, which, with appropriate apparatus, was a gift to the University from the Chancellor, the Duke of Devonshire. The admirable arrangements of this building were designed and carried out by Maxwell. In October, 1871, he delivered an introductory lecture, in which he made some very valuable observations on scientific education and the advantages afforded by the study of experimental physics, especially to that class of students in Cambridge which has produced so many distinguished mathematicians. Addressing such students in particular, he warned them of the preliminary difficulties they would have to face in attempting to combine experimental practice with theory, but suggested at the same time motives which should encourage them to persevere in their efforts.

Besides the duties directly incumbent on a Professor of Physics, the preparation of treatises on the subjects of his chair now engaged Maxwell's attention. "The Theory of Heat," the first edition of which appeared in 1871, was at once hailed as a beautiful exposition of a comparatively new and interesting subject. This work is indeed a model of scientific style, almost unique in the freshness and simplicity of its expositions, and possessing altogether a charm for the student of physical science, such as few other works of the kind are capable of imparting. The Treatise on Electricity and

Magnetism was published in 1873; an original and splendid work, destined, it is not rash to predict, to give colour and direction to our speculations on these subjects for many years to come.

Nor must we omit another species of work always performed by Maxwell kindly and conscientiously, professorial work, surely, of the very highest kind, that, viz., of reading and reporting on papers contributed to learned societies by young aspirants to scientific fame. This kind of work, of which much fell to Maxwell's share, is but little known to the outside world, but involves when carefully performed a vast expenditure of time and trouble even on the part of the most accomplished specialist.

Besides performing these various duties, Maxwell took an active part in conducting the general business of the University, serving on the University Council, and otherwise, but especially in effecting those changes in the mathematical studies of Cambridge, which may be said to have amounted at this time almost to a revolution. In accomplishing this, his published treatises already referred to bore in themselves a most important part, but the active share he took in drafting the scheme of the new examination, and the admirable questions he constructed in his capacity of examiner, no less contributed to the desired changes which were thus, thanks in a great measure to his sagacity, gradually and skilfully effected.

The direct influence of Maxwell on Cambridge studies began to be felt in 1866, when he filled the office of Moderator in the Mathematical Tripos. Maxwell's questions infused fresh life into the Cambridge Tripos, and, therefore, into the University studies, by the number of original ideas and new lines of thought opened up by them, thus preparing for the change of system in 1873, when so many interesting subjects were added to the examination.

From 1871 to 1879, Maxwell's pen was incessantly busy. He wrote numerous more or less important mathematical papers, as well as a great many essays and reviews, to be found in the pages of "Nature." He also contributed several interesting articles to the "Encyclopædia Britannica."

Of his papers published during this period, those which probably rank highest in point of importance are the two memoirs connected with the Kinetic Theory of Gases. Another undertaking in which he was long engaged, and which, though it proved to be exceedingly interesting, entailed a great deal of labour, was the editing of the "Electrical Researches" of the Hon. Henry Cavendish. This work, published in 1879, has had the effect of increasing the reputation of Cavendish, disclosing as it does the unsuspected advances which that acute physicist had made in the theory of Electricity, especially in the measurement of electrical resistance. The work is enriched by a variety of valuable notes, in which the editor has sought to examine

Cavendish's views and results by the light of modern theory and methods. Especially valuable are the methods applied to the determination of the electrical capacities of conductors and condensers, a subject in which Cavendish himself showed considerable skill, both of a mathematical and experimental kind.

During the later months of 1878, and the beginning of 1879, Maxwell's health was not good, but no apprehensions of anything serious were felt by his friends. In the month of May of the latter year he looked very ill. Hopes were entertained, however, that when he returned to the bracing air of his country home he would soon recover. But it was not to be. He lingered through the summer months at Glenlair, with no signs of improvement, his spirits gradually sinking. As a last resource he was brought back to Cambridge in October that he might be under the charge of his favourite physician, Dr. Paget. Nothing, however, could be done for his malady, and, after a painful illness, he died on the 5th of November, 1879, in his 49th year.

It is difficult to convey a correct impression of the variety and extent of Maxwell's information on all sorts of subjects. Knowledge of every kind was interesting to him, and there were few topics of conversation to which he could not bring his own peculiar light. He was almost as much at home with the students of philosophy and theology as with those of physics. But if there was one subject more than another in which his conversation was always interesting, it was the literature of his own country, his acquaintance with which, and especially with English poetry, was remarkable alike for its extent, its exactness, and the wide range of his sympathies. His critical taste, founded as it was on his native sagacity, and a keen appreciation of literary beauty, was so true and discriminating that his judgment was in such matters quite as valuable as on mathematical writings.

He wrote often in verse, chiefly poetical epistles to intimate friends, and occasional epigrams, but none of these have been published. The published pieces are few in number, all dealing with some scientific movement, speculation or incident of the hour, and all conceived in a spirit of happy good-humoured banter. With the exception of "Notes on the President's Address," British Association 1874, when Dr. Tyndall was President, which appeared in "Blackwood," these pieces are to be found in the pages of "Nature," under the signature $\frac{dp}{dt}$. The invention of this signature is due to Professor Tait, in whose work on Thermodynamics, one of the equations of the subject is written in the form $\frac{dp}{dt}=JCM$, the right hand side of the equation being Maxwell's initials.

The list of Maxwell's published memoirs and writings of every kind, exclusive of treatises, is a long one, numbering over 100 papers, many of which contain speculations of a profound character, worked out with elaborate details of calculation. They treat of a variety of subjects, the most important of which are—(1.) Electricity and Magnetism; (2.) The Kinetic Theory of Gases; (3.) Colour Perception; (4.) Dynamics, including Astronomical Physics; (5.) Elasticity; (6.) Optics. The two first named attracted more of his attention than the others, and his writings on them form a sort of continuous series in which we can follow the history of his ideas so as almost to trace their gradual development.

Thus, his first memoir on Electricity, entitled "On Faraday's Lines of Force," possesses an interest apart from its intrinsic value, containing as it does the germs of the theories and methods which reached their full growth in his great treatise on Electricity and Magnetism. This memoir is in two parts, differing in object and treatment. Whilst the first half aims at a vivid representation of Faraday's conception of lines of electric and magnetic force, the second is a mathematical exposition of what Faraday calls the electrotonic state of bodies, and an analytical investigation, based on Faraday's laws, of the electromotive forces acting on a conductor due to the motion of magnets or currents of electricity outside of it.

Faraday's doctrine that electric and magnetic effects are conveyed by a medium and not by action at a distance, found in Maxwell an ardent believer, who set himself the task of searching out by what kind of mechanism this is accomplished. His first attempt at an explanation is contained in a series of papers in the "Philosophical Magazine," 1861-62. Beginning with magnetic phenomena, he points out that a medium transmitting magnetic action must be under a stress in which there is excess of pressure in all directions perpendicular to the lines of force, in other words, a stress consisting of a tension in the direction of the line of force combined with a hydrostatic pressure. A stress of this character would be produced by a system of molecular vortices, the axes of which are in the direction of the lines of force. A similar representation may be made of the stress due to the magnetic action of electric currents.

Taking, then a system of such vortices, he finds that the most general form of the expressions for the force components, due to the vortices at any point of the medium, is identical with that which would arise from magnets and electric currents. In the course of the work the magnetic force is identified with the velocity of the vortex, and the coefficient of magnetic induction is π times the density of the medium, or $\mu = \pi\rho$. The chief difficulty is in the geometrical conception of the motion of the vortices, two parallel vortices moving in opposite directions in those parts where they are contiguous. Maxwell gets over this difficulty by supposing that the vortices are separated by layers of particles revolving, like "idle wheels" in mechanism, each on its own axis, in directions opposed to those of the vortices. The motion of those particles he identifies with electric currents in the medium, and the description of how, by this mechanism, induced currents are originated, forms an interesting part of the theory. The electro-motive forces, that is, the forces on the particles from the vortices, are then found in the most general case of a medium in motion, the expressions being identical with those given in the "Electricity and Magnetism," ii, § 598.

Turning next to Statical Electricity, if we consider a dielectric under inductive action, we may conceive the electricity in each of the particles described above to be displaced, so that one side of the particle is positive and the other negative, the total quantity remaining the same. The general effect on the dielectric will, therefore, be a displacement of the electricity, which will disappear when the exciting cause disappears. We have here, then, something analogous to the phenomena exhibited by an elastic body under a state of stress, but recovering its form when the stress is removed.

If we denote the displacement by h, on this analogy the force will be given by an equation of the form $R = -4\pi E^2 h$, where E is a constant depending on the dielectric. In addition to the properties already described of the cells constituting the vortices, we must now suppose the substance of which they consist possessed of a certain elastic resilience, affecting by its tangential action the velocities of the particles, and in its turn affected by them, being distorted and thrown into a state of stress. If, for simplicity, we omit the magnetic effects and suppose the cell to be spherical in form, and that its coefficients of cubic elasticity and rigidity are $\frac{5}{6}m$ and m, such being the relative values of these quantities in an isotropic elastic medium according to the theory of Navier and Poisson, then it can be shown that $E^2 = \pi m$. But the rate of propagation of transverse vibrations in an elastic medium is given by $V = \sqrt{m/\rho}$. And $\mu = \pi\rho$. Hence $E = V\sqrt{\mu}$. Now, the force between two charges e_1, e_2 at distance r, can be deduced from the theory, viz., it is $E^2 e_1 e_2 / r^2$. Hence the number of electrostatic units in one unit of the Vortices Theory, *i.e.*, of the Dynamical or Electromagnetic Theory, is E. If the medium be air $\mu = 1$, and therefore $V = E$. The value of E found by Weber and Kohlrausch was 310,740,000 metres. On comparing this with Fizeau's value of the velocity of light in air, viz., 314,858,000 metres per second, Maxwell drew the inference, that "light consists in the transverse undulations of the same medium, which is the cause of the electric and magnetic phenomena." He also proved that the specific inductive capacity of a dielectric varies as the square of the index of refraction, and inversely as the coefficient of magnetic induction. The last point discussed under the Vortices Theory is Faraday's discovery of the rotation of the plane of polarisation of polarised light transmitted along the lines of magnetic force. To the question, how will the vibrations be affected by passing through a medium in a state of rotation, Maxwell's results, as deduced from the theory, are in close accordance with the experimental laws given by Verdet.

The deductions drawn by Maxwell from his theory of Molecular Vortices were of so striking a character that it was impossible his mind could rest till he had still further examined their truth. Accordingly we find that in less than three years after their publication he presented to the Royal Society a memoir, entitled "A Dynamical Theory of the Electromagnetic Field." This, the most splendid of all his papers, places the theory of action through a medium on broader dynamical principles, and traces the connexions between the various characteristic quantities of the subject, twenty in all, more simply and more directly than he had formerly done. No adequate idea of this memoir can be given in a short notice, for it contains matter enough, and on so many different branches of the subject, to furnish the texts of many ordinary papers. The electromagnetic field is treated as a dynamical system possessed of different kinds of energy and under the action of various forces, the connexions between which are laid down with admirable clearness. General mechanical principles are employed to illustrate the significance of the laws discovered by Faraday, and from this aspect and without the hypothesis of any particular mechanism, the equations of the electromagnetic field are simply deduced. But besides this there are many interesting side issues and expositions. Among these may be mentioned an experimental method of determining coefficients of induction by the electric balance, a theory of condensers, and the calculation of the self-induction and mutual induction of circular coils of wire. The part of the memoir, however, which excites the liveliest interest, is the investigation of the electromagnetic theory of light. The two grand results previously established by the theory of vortices are again proved, but without the aid of somewhat doubtful hypotheses, while in addition a very substantial confirmation of Maxwell's views is obtained by the deduction of an equation for the velocity of wave propagation of electromagnetic disturbance in crystallised media identical with that found by Fresnel for light. Maxwell published a few years later the results of some experiments he had made to determine the ratio of the electric units. His number is 288,000,000. Sir William Thomson found 282,000,000. When we compare these numbers with that of Weber and Kohlrausch, it cannot be said that this quantity has yet been definitely determined. The same is true of the velocity of light, the lowest value of which is 298,000,000 metres per second. We cannot, therefore, affirm with certainty that Maxwell's inference is correct, but there is a strong *primâ facie* presumption in its favour.

The papers to which we have called attention by no means exhaust the list of Maxwell's contributions to electrical science, but they are the most important. Most of what he wrote found its proper place in the treatise on Electricity and Magnetism, which is in a great measure the outcome and product of his study of Faraday's researches and of his own speculations and labours.

The theory that the properties of a gas are due to the action of invisible molecules in rapid motion was propounded by several writers before Maxwell, and an explanation had been given of Boyle's law that the product of the pressure and volume of a gas is constant for the same temperature.

Herapath had also given an explanation of diffusion, and Joule had calculated the mean velocity of the molecules of various gases. The most important advance was, however, made by Clausius, whose first memoir "On the kind of motion which we call heat" contains a very clear exposition of the theory, and establishes that the *vis viva* of the translatory motion of the gas does not represent the whole of the heat in it. His second memoir treats of the mean length of path described by a molecule, and an expression is obtained for it in terms of the average distance of the particles, and the distance between their centres at collision. The paper is valuable not so much on account of this result, which in fact is different from that subsequently obtained when the subject was more fully developed, but because it led the way in bringing the kinetic theory fairly under the domain of mathematics.

Maxwell perceived the importance of Clausius' work, and his first paper contains an attempt to complete the investigation of the mean path. This paper, entitled "Illustrations of the Dynamical Theory of Gases," was read before the British Association in 1859, and published in the "Philosophical Magazine" of the following year. Theories, mathematically developed, are here given of the internal friction of gases, the conduction of heat through a gas, and the diffusion of one gas through another. One or other of these phenomena, he thought, ought to yield an accurate expression for the length of the mean path.

He supposes the molecules to be hard perfectly elastic spheres, and investigates the laws of motion of a system of such molecules acting on one another, only during impact. His method is first of all to discuss the motion of two molecules under their mutual action, and having discovered the changes in their velocities and directions due to an encounter, to apply what he has happily termed the statistical method to determine the mutual action of two systems. The methods he employs for this purpose, founded on the mathematical theory of probabilities, are remarkable for their elegance and for greater generality than had been attempted by previous writers.

Maxwell's next contribution to the Kinetic Theory of Gases was the Bakerian Lecture to the Royal Society in 1866, "On the Viscosity or Internal Friction of Air and other Gases." This is an account of experiments to determine the coefficient of gaseous friction. He employed for this purpose the oscillations of three disks placed between fixed disks, and capable of motion about a common axis, the quantity observed being the successive times of oscillation of the movable disks. The chief results of this paper are, that the coefficient of friction is (1) independent of the density of the gas, (2) proportional to its absolute temperature.

The second of these laws involves the rejection of the hypothesis of the impact of hard elastic particles, leading as it does to proportionality of the square root of the temperature. Accordingly, Maxwell's next memoir "On the Dynamical Theory of Gases," following closely on the Bakerian Lecture, propounds a theory in closer agreement with his experiments. Instead of hard elastic spheres, he now substitutes "small bodies or groups of smaller molecules, repelling one another with a force whose direction passes very nearly through the centres of gravity of the molecules, and whose magnitude is represented very nearly by some function of the distance of the centres of gravity." The necessity of supposing groups of molecules arises from the fact that, in a body of invariable form, the motions of its parts relatively to the centre of gravity consists entirely of rotations which the supposed force is incapable of generating, whereas a group of loosely-connected bodies may have oscillations among themselves as well as rotations. That the energy of the system cannot be entirely translational had been previously pointed out by Clausius.

In this memoir the statistical method is restated more fully, clearly, and systematically than before, but the only law of force between the molecules which leads to simple results is the inverse fifth power of the distance. This law being adopted, the general equations resulting are applied to a variety of problems: in (*a*), proving Dalton's law for the pressure of a mixture of gases; (*b*), explaining Graham's experiments on the diffusion of carbonic acid and air; (*c*), proving Graham's law for the interdiffusion of gases contained in different vessels connected by a very small hole; (*d*), finding the equilibrium condition as regards temperature for a mixture of gases, and again establishing Gay-Lussac's law; (*e*), finding expressions for the specific heats of gases on Clausius' assumption that the whole energy bears a constant ratio to that of translation; (*f*), proving the laws of viscosity, the same as those stated above; (*g*), finding the viscosity of a mixture of gases, which, if not in close agreement with the results of Graham's experiments, at least exhibits the same general peculiarities; (*h*), proving that in a column of air the temperature is independent of gravity; (*i*), deducing an expression for the conductivity.

It is impossible to read this comprehensive memoir without being impressed by the boldness and sagacity of the author's genius, or without admiring the simplicity of system he has introduced into a subject, at first sight unapproachable from its difficulties. At the same time, we must remember that the hypothesis on which he builds is a particular one, and could only be accepted on its being found that the conclusions are borne out by facts. Now the law that the viscosity varies as the absolute temperature has not been verified by other experimenters on this subject. It has been found that the law of variation is a power of the temperature somewhat lower than the first. But though we cannot, therefore, accept the author's conclusions without qualification, we must still regard his investigation as a brilliant and determined effort to reach the true theory to which it must form a close approximation.

The methods employed by Maxwell were afterwards generalised by Boltzmann, who succeeded in so modifying the proofs of many of the theorems as to make them independent of any hypothesis as to the nature of the encounter between the molecules. Maxwell to some extent adopted Boltzmann's more general treatment of the theory in his next memoir (1878) "On Stresses in Rarefied Gases arising from Inequalities of Temperature;" but he ultimately found himself compelled to fall back on his former special hypothesis. In this memoir he aims at an explanation of the forces producing motion in Crookes's Radiometer.

The statistical computation of the motion of a gas deprived of that regularity which uniformity of temperature permitted is by no means easy, and accordingly the work forms an elaborate application of the principles developed in the paper of 1866. It is shown, however, that the effect of inequality of temperature is to produce a stress in the gas whose components are comparable with the forces necessary to produce the motion of the radiometer wheel. If we take account only of the normal components of this stress it is possible to frame an explanation of that motion by their agency. When, however, the general equations of the motion of the gas are also determined, it appears that so long as the flow of heat is steady the equations are the same as when the temperature is uniform. "How, then, are we to account for the fact that forces act between solid bodies immersed in rarefied gases, and this apparently as long as inequalities of temperature are maintained?" The explanation, Maxwell thinks, is to be found in the fact that the gas in contact with the surface of a solid must slide over it with a finite velocity in order to produce a finite tangential stress. This he is not able to show, but in an appendix to the memoir added in May, 1879, the conditions which must be satisfied at the boundary between a solid and a gas are investigated in a very ingenious manner, the results showing that "a gas may slide over the surface with a finite velocity, and that this velocity and the corresponding tangential stress are affected by inequalities of temperature at the surface of the solid, tending to make the gas slide from colder to hotter places." The latter result, as a deduction from the Kinetic Theory, had been previously obtained in another way by Professor O. Reynolds. The stress which is the result of this theory would help to account for the radiometer motion. In this memoir are interpolated various notes dated May, 1879, in which the application of Spherical Harmonics is briefly indicated as a means of simplifying the mathematical parts of the work. The failure of the author's health prevented him from afterwards following out this interesting extension of the subject.

Another important memoir was presented to the Cambridge Philosophical Society in May, 1878, "On Boltzmann's Theorem on the Average Distribution of Energy in a System of Material Points." This paper is remarkable alike for the comprehensive character of the assumptions as regards the forces acting between the points, the closeness and condensation of the reasoning, and the generality of the theorems proved. It is impossible, however, to describe them with sufficient brevity in a short notice. Passing to the particular problem of the equilibrium of temperatures of two gases, we find the author once more examines Gay-Lussac's law, and points out that the theorem that the average kinetic energy of a single molecule is the same for molecules of different gases, is not sufficient for the equilibrium of a mixture of gases, because we have no means of finding out the separate temperatures of the two; the case would be different if the gases were separated by a diaphragm. Another interesting application of the general results is made to the theory of Loschmidt's experiments on the diffusion of gases. These experiments were made with a tube into which was put a gas or a mixture of gases, and the tube was then whirled about one end; and the ultimate distributions of the gases, with the times of attaining to them, formed the subject of investigation.

From this review of Maxwell's chief contributions to the Kinetic Theory of Gases, imperfect though it be, it will be seen that, if he was not the discoverer of this new region of inquiry, he yet explored it more thoroughly than any of his predecessors; he bore a leading part in evolving the general laws to which it must be subject, reducing it to order, and pointing out in what directions it would be most fruitful.

Maxwell took up the theory of Colour Perception at the point where Young had left it. According to Young's theory, there are three distinct varieties of nerves, sensitive to red, green, and violet light respectively, and by the superposition of these sensations when aroused in the sensorium the colours of external objects are represented. Maxwell's object was to submit this theory to the test of measurement. For this purpose he employed an apparatus now well known as his Colour Top, in which a system of coloured disks could be arranged round the axis of the top, so that a sector of any required angular magnitude of each colour might be exposed. When this system was spun rapidly it assumed the appearance of a single tint. Young had himself employed an apparatus of a similar character, consisting of circles painted with different colours. The merit of Maxwell's top is in the ease with which the proportions of the colours can be changed and definite measures taken of them. His plan of experimenting was to obtain matches between various mixtures of colours from the coloured disks, and these matches were expressed by colour equations. Having selected three colours as standards of reference, the choice being guided by the variety of combinations producible from them, he was enabled, from the great number of colour equations he obtained, to construct a colour diagram on the principle suggested by Newton. The standard colours being at the angular points of an equilateral triangle, any other colour, with a proper coefficient attached to it, could be represented by a point in the diagram, so that from a knowledge of this coefficient and the position of the point, it is possible to say how the colour in question may be obtained from the standards or combined with one or two of them to form a match with the remainder. Any colour which can be produced by a mixture of two of the standards will be represented by a point on the side of the triangle joining them, and any colour from a mixture of the three by a point inside the triangle. Had the standards, instead of being arbitrary, been the three primary colours, any other colour would be obtainable from them by their mixture. Maxwell shows how one of the primary colours may be obtained. Colour-blindness is due to the absence of one of the three primary sensations, and therefore from the colour equations of the colour-blind it is possible to localise on the diagram the tint corresponding to the absent sensation. From experiments on two colour-blind subjects he found the tint was a red approaching to crimson.

The Colour Top was afterwards abandoned for another apparatus of an ingenious character, known as the Colour Box, by means of which the proportions of three colours forming white light of constant intensity could be accurately measured. The main object of the measurements was to determine the positions of the colours of the spectrum on the colour diagram. The standard colours in this case were red, green, and blue of ascertained wave-lengths. In all, sixteen definite points of the spectrum were examined, these points being determined by a contrivance in the apparatus for obtaining measures by which the wave-lengths of all the colours admitted could be found. The results of these elaborate experiments showed that from the red to the green the positions lie nearly in one straight line, and from the green to the blue in another, the chief divergence being at the red and blue ends. The conclusion is that there are three primary colours in the spectrum, red, green, and blue, by mixture of which colours chromatically identical with the other colours of the spectrum can be obtained. The position of the green is one-fourth from the line E towards the line F, but the red and blue cannot be satisfactorily placed. Young's theory was examined by Helmholtz as well as by Maxwell, with the like result, which was to confirm its truth.

If we pass to other subjects we must regard the essay on Saturn's Rings as a most valuable investigation on account of the important results it contains. Some of these we will now mention. The author first establishes that the stability of a uniform solid ring revolving round the planet is impossible. If we suppose the ring loaded at a point of its circumference a possible case of stability is obtained, but the load must be between ·8158 and ·8279 of the whole mass of the ring. So irregular a distribution of the mass is very improbable, and would be found by observation. When, in addition, we consider the immense size of the rings—an iron ring of such a size would be exceedingly plastic under the forces it would experience,—when we consider also their comparative thinness, it is impossible to regard them as rigid. The stability of a ring of equal satellites is then examined. Disturbances perpendicular to the plane of such a ring cannot produce instability. In the plane of the ring the greatest danger to stability will exist when the number of undulations of the circle of satellites supposed oscillating about their mean positions is the greatest possible, that is, when equal to half the number of satellites. In that case, for stability, the mass of the planet must be greater than $\cdot 4352\mu^2$ times the mass of the ring, where μ is the number of satellites. If this condition hold, four distinct oscillations of different periods and amplitudes will run round the circle of satellites. Results similar in their general outlines, though necessarily characterised by greater complexity, hold in the case of a ring of unequal satellites. The next hypothesis examined is that of an annular cloud of meteoric stones revolving uniformly about the planet. It is shown that the average density of such a cloud must be less than 300 times that of the planet, otherwise destructive oscillations will be set up in the ring.

So low a density has been shown by Laplace to be impossible in a ring revolving as a whole, so that the outer and inner portions cannot have the same angular velocity.

The final conclusion is that the rings of Saturn are composed of an indefinite number of free particles revolving round the planet with velocities depending on their distances from his centre. The particles may be arranged in a series of concentric rings, or they may form a confused multitude revolving, but not arranged in rings, and constantly coming into collision. In the first case the mutual perturbations of two rings may at length reach so great a magnitude as to cause their destruction. In the second the destructive tendency is more rapid, though it may be retarded by the particles settling down into concentric rings.

The most important contributions by Maxwell to the theory of Elasticity are his paper on "Reciprocal Frames and Diagrams of Forces," printed in the "Philosophical Magazine," 1864, and a memoir under an almost identical title read to the Royal Society of Edinburgh in 1870. These papers contain many beautiful theorems on the geometry and mechanics of frameworks, interesting from a purely theoretical point of view, but also leading to important practical results. The memoir of 1870 constitutes a substantial addition to the subject of elasticity, and some of the graphical methods have been adopted and extended in works on engineering. The mathematical treatment of the graphical method of internal stress in this paper is remarkable for the beauty and symmetry of the expressions and theorems obtained.

In the foregoing sketch of Maxwell's writings we have grouped them according to subjects rather than dates, thinking that in this way a clear view would be gained of what he actually did in each subject. We have thus been enabled to bring into prominence his greatest memoirs and their connexions with one another. But there is still a large number of mathematical papers, struck off from time to time, and more or less important, of which we must omit any detailed account. Among these are his papers on The Dynamical Top, on Governors, on the General Laws of Optical Instruments, on Hamilton's Characteristic Function. There is also a large class of miscellaneous essays on scientific subjects, which, though not marked by the same intellectual power as his great memoirs, are yet possessed of distinctive excellences of their own. This class comprehends (*a*) Articles in the "Encyclopædia Britannica," to which may be added an elementary manual on Matter and Motion; (*b*) his Addresses to the British Association, to the London Mathematical Society, and the Chemical Society, the Rede Lecture at Cambridge, and Lectures at the Royal Institution; (*c*) Essays and Reviews contributed to "Nature."

In some of these essays the author allowed himself a greater latitude in the use of mathematical symbols and processes than in others, the articles "Atom," "Capillary Attraction," "Constitution of Bodies," "Diffusion," in the "Encyclopædia Britannica," being, in fact, brief treatises on these subjects treated mathematically. The subjects of his lectures and addresses were, in the majority of cases, one or other of those three departments of physics he had done so much to extend—Colour Perception, Action through a Medium, Molecular Physics. The Reviews in "Nature" were criticisms of important memoirs or treatises on subjects in which he was interested.

In the whole series of these writings we find the same clear and graceful delineation of principles, the same beauty in arrangement of subject, the same force and precision in proofs and illustrations. The style is simple and singularly free from any kind of haze or obscurity, rising to a strain of subdued eloquence whenever the emotional aspects of the subject overcome the purely speculative. In the memoirs and the treatises we find a like clearness in the statement of principles combined with the use of an analysis at once direct and forcible, though perhaps unnecessarily condensed. It is seldom that the faculties of invention and exposition, the attachment to physical science and capability of developing it mathematically, have been found existing in one mind to the same degree. It would, however, require powers somewhat akin to Maxwell's own to describe the more delicate features of the works resulting from this combination, every one of which is stamped with the subtle but unmistakeable impress of genius.

Dr. John Jeremiah Bigsby was born at Nottingham on the 14th August, 1792. He was the eldest son of Dr. Bigsby, who practised for many years at Nottingham; and, as he was destined for the medical profession, he was sent first to St. Andrew's and afterwards to Edinburgh University to pursue his medical studies.

In 1814, he received the degree of Doctor in Medicine from the University of Edinburgh; and, with the object of acquiring a practical knowledge of his profession, he obtained in the same year the appointment of resident physician (or physician's clerk as it was then named) in the Edinburgh Infirmary, the duties of which office he discharged with great assiduity, while from his amiable disposition, and the interest he took in his work, he won the esteem of everyone with whom he became associated.

After the practical experience he had gained in the infirmary he entered the medical department of the army in 1816, and was employed for some years in various parts of Canada, which not only gave him the opportunity of improving his knowledge as a military practitioner but fostered a growing taste for geological pursuits, which latter was subsequently greatly strengthened by visiting various parts of the United States, including New York, Washington, and Philadelphia. His reputation as a geologist led to his being appointed, in 1822, Secretary and Medical Officer to the Boundary Commission which had been in operation for a few years.

Dr. Bigsby left the army in 1823, and settled in Newark-on-Trent, where he practised his profession as a consulting physician for a period of more than twenty years, and having acquired, partly by marriage, a moderate competence, he finally settled in London as a retired physician, where he resided during the rest of his long and well-spent life.

He had now leisure and opportunity for pursuing his favourite geological investigations, and became a contributor to the "Transactions of the Geological Society," of which he had been for many years one of the Fellows, as well as to those of American Societies. But the work by which Dr. Bigsby was chiefly known, and to which he had devoted almost exclusively the last twenty-five years of his life, was entitled "Thesaurus Siluricus," which comprised a list of such of the Silurian fossils as had been described. This work was published in 1868, a grant having been made in aid of its publication from the Government Grant. In the following year Dr. Bigsby was elected a Fellow of this Society, and in the same year received the Murchison medal from the Geological Society.

To show his interest in geology, Dr. Bigsby presented, some years ago, a sum of money to the Geological Society for the purpose of founding a medal to be adjudicated biennially by the Council for the promotion of geological science, the stipulations being that, preferentially, the recipient should have studied American geology, should not be more than 45 years of age, and "thus probably not too old for further work, and not too young to have done much."

Dr. Bigsby's scientific attainments were not more remarkable than his many estimable qualities in private life. For many years—indeed to the end of his long life—he was noted for his unostentatious charity, and for the unceasing interest he took in the education of the poor children in his immediate neighbourhood. His well-stored mind and his geniality rendered him a most agreeable companion, and endeared him to a large circle of attached friends. He was, in every respect, the type of a Christian gentleman. His last illness was short, and he passed away without suffering at his residence in Gloucester Place at the advanced age of 89.

John Gould, the Ornithologist, or the "Birdman" as he preferred to call himself, was born of humble parentage at Lyme Regis, in Dorsetshire, in November, 1804. When the boy was about fourteen years of age his father was appointed foreman of the gardeners at Windsor Castle, and Gould became one of the staff. Under the care of Mr. J. T. Aiton, the head gardener of the Royal Gardens, Gould passed several years, and during this period seems first to have exhibited the intense love of birds and bird-life which has rendered his name so justly celebrated.

About the year 1827, Mr. Vigors required a taxidermist for the collection of the newly-formed Zoological Society of London, and asked for an exhibition of the skill of the various applicants for the post. Gould's artistic talent in bird-stuffing, which he had studiously cultivated for some years, rendered him *facile princeps* among the competitors, and obtained him the appointment. While occupant of this post in 1830, Gould received a collection of bird skins from the Himalayas—a district at that time almost unexplored. This opportunity Gould embraced with characteristic energy, and thus laid the foundation of his fame and fortune. Mr. Vigors was naturally anxious to describe the novelties, and Gould employed his lately married wife, who had been educated as a governess, and had great artistic talent, to figure them. Thus was produced Gould's first illustrated bird book—the so-called "Century of Birds from the Himalaya Mountains," by far the most accurately illustrated work on foreign ornithology that had been issued up to that period. In size the "Century" rivalled the folios of Le Vaillant, but far surpassed them in the excellence of the plates.

The success of the "Century" was so great that in 1832 the "Birds of Europe" was commenced on a similar scale, and completed in due course in five volumes, while during the progress of this work the first editions of the well-known "Monographs" of the Toucans and Trogons were also issued, and frequent contributions made to the Zoological Society's "Proceedings" and "Transactions."

We now come to the most important and striking episode of Gould's career. The birds of the great continent of Australia were at that time almost unknown, except from the scattered notices of older authors, and from an essay by Vigors and Horsfield on the specimens from that country contained in the Linnean Society's collection. Gould determined to make a special expedition to Australia for the purpose of investigating its ornithology. In 1838 he left England for this purpose, accompanied by his wife, and devoted two years to the exploration of Tasmania, South Australia, and New South Wales. A large series of birds' skins as well as of their nests and eggs were collected, besides specimens of the mammals, while a mass of valuable and original observations were made upon their habits and distribution. On Gould's return to this country, the great folio work on the "Birds of Australia" was at once commenced, and completed in 1848, after seven years' unremitting labour. The companion work on the "Mammals of Australia," forming three volumes, with 182 plates, was completed in 1860.

After the "Birds of Australia," the most important work accomplished by Gould was certainly his "Monograph of the Trochilidæ," or "Humming Birds," commenced in 1850, and finished in 1861. For many years Gould had been an assiduous collector of specimens of this lovely group, and in 1851 exhibited his collection in the gardens of the Zoological Society. Very large additions, however, were made to it after that period, and in fact, continued to be made until within a short period of his death, so that in the collection recently acquired by the British Museum, there were upwards of five thousand examples of birds of this family.

Shortly after the completion of the "Humming Birds," Gould commenced his work on the "Birds of Great Britain," which he affirmed had never been properly illustrated. Whatever may be other opinions upon this point, it is certain that Gould's five volumes upon this subject, which were completed in 1873, added vastly to our knowledge upon many points, besides giving us the most complete set of pictures of our native birds yet issued. Special pains were bestowed on the plates of this work, which may in some cases, perhaps, be said to be slightly overcoloured, but the natural attitudes of the various species, and the selection of appropriate surroundings, have never been surpassed in any work of natural history.

Besides the works already specially mentioned, Gould issued other folio volumes, such as the "Monograph of the Odontophorinæ," and second editions of the "Toucans" and "Trogons," the whole series forming altogether forty-one folio volumes, illustrated by 2999 plates, a performance quite unrivalled in any other branch of literature. Gould was also the author of upwards of 300 memoirs and papers published in the "Proceedings of the Zoological Society," and in other periodicals. For the last five or six years of his life, Gould was in failing health. Though suffering from a tedious and painful malady, he never ceased to work, and even within a few months of his death had planned a new monograph, and issued the first part of it. Gould died on the 3rd of February, 1881, in his seventy-seventh year, in his house in Charlotte Street, near the British Museum, where he had lived for the last twenty years of his life. His collection of birds has passed, to the great satisfaction of all naturalists, into the collection of the British Museum. Gould was elected a Fellow of the Royal Society in 1843, and was for many years an active Member of Council and Vice-President of the Society with which he had become originally connected in the humble capacity of bird stuffer.—P. L. S.

Robert Mallet was born in Dublin on the 3rd June, 1810, and died in London on the 5th November, 1881. He was the son of Mr. John Mallet, well-known as an ironfounder in the city of Dublin. He entered Trinity College in 1826 and graduated in Arts in 1830. He became a member of the Royal Irish Academy in 1832, of the Society of Civil Engineers of Ireland in 1836, and of the Chamber of Commerce of Dublin in 1837, and afterwards became an Associate and Member of the Institution of Civil Engineers of England in 1839 and 1842.

He obtained, in 1841, the Walker Premium from the Institution of Civil Engineers for raising the roof of St. George's Church, Dublin.

Robert Mallet was elected an honorary member of the Society of Arts of Scotland, 1840, of the Academy of Science, Arts, and Belles Lettres of Dijon (1853), a Fellow of the Royal Society (1854), an honorary member of the United Service Institution (1857), Fellow of the Geological Society of London (1859), and corresponding member of the Physical Class of the Royal Philosophical Society of Göttingen, 1869.

In 1846, Robert Mallet read before the Royal Irish Academy, a remarkable paper on the "Dynamics of Earthquakes," which was the commencement of a long series of contributions to a branch of physical geology with which his name will always be associated. The chief of these contributions were (in addition to that just named):—1. Earthquake Catalogue of the British Association (1858).* 2. The Great Neapolitan Earthquake of 1857 (2 vols., 1862). 3. Volcanic Energy ("Phil. Trans.," 1872).

For these valuable contributions to physical geology he received the Cunningham Medal of the Royal Irish Academy (1862), and the Wollaston Medal of the Geological Society of London (1877).

In 1855 he read before the Royal Irish Academy a paper on the Construction of Artillery of a large Calibre, in consequence of which he was elected a special honorary member of the Royal Artillery Institution, Woolwich (1867).

In 1859 he received the Telford Medal of the Institution of Civil Engineers, for his paper on the Coefficients of Elasticity and Rupture in Wrought Iron.

In scientific thought, Robert Mallet was remarkable for the originality of his ideas, and for the broad grasp he took of every subject that engaged his attention; in private and social life he was beloved for the kindness, geniality, and humour of his disposition, for his readiness in conversation and uniform good temper.

S. H.

Arthur Penrhyn Stanley, D.D., Dean of Westminster, died after a brief illness, on the 18th of July, 1881, in the sixty-sixth year of his age. The profound sorrow with which the unexpected announcement filled the hearts of all persons in the country of every class and creed, from the Queen, of whom he was, to use her own words, a "most trusted friend and adviser," to the poorest of her subjects, has been so abundantly chronicled in newspapers, magazines and sermons, that it need not be further referred to here. Nor is this the place to speak in any detail of his remarkable position as an ecclesiastical politician, as a theologian or historian; but though without claims to be considered a man of science, so eminent a Fellow of the Society must

* In preparing this catalogue he was assisted by his son, J. W. Mallet, at that time Professor of Chemistry in the University of Alabama.

not be allowed to pass away without some record of his career in our obituary notices.

Dean Stanley was born at Alderley in Cheshire, on December 13th, 1815. His father, a brother of the first Lord Stanley of Alderley, and then Rector of the parish, was afterwards better known as the energetic, liberal, and enlightened Bishop of Norwich, who among many other accomplishments, was an enthusiastic ornithologist, the author of a still favourite book, the "Familiar History of Birds," and for many years President of the Linnean Society. The future Dean, though he did not inherit his father's taste for science, always took interest in and welcomed its progress. This spirit, which pervaded all his writings and conduct, may be illustrated by the following characteristic passage from his sermon on Sir Charles Lyell, preached in Westminster Abbey in 1875, "The tranquil triumph of geology," he says, "once thought so dangerous, now so quietly accepted by the church, no less than by the world, is one more proof of the groundlessness of theological panics in the face of the advances of scientific discovery." He was educated under Dr. Arnold, at Rugby, and commenced a brilliant career at Oxford by obtaining a scholarship at Balliol, and shortly after the Newdigate Prize for his English poem, "The Gipsies." After gaining the Ireland scholarship, he took a first class in classics in 1837, gained the Chancellor's prize for the Latin Essay in 1839, won the English Essay and the Ellerton Theological Prizes, and was elected a Fellow of University College in 1840, where for twelve years he was tutor. He did good service in the cause of university reform, by acting as Secretary to the Oxford University Commission of 1850–52, and was about the same time made a Canon of Canterbury Cathedral. In 1853, he returned to Oxford as Regius Professor of Ecclesiastical History, and Canon of Christchurch, which office he held until his appointment in 1863 to the Deanery of Westminster, a position which he held up to the time of his death, and which he filled in such a manner as to have given the Abbey a place in the history of the religious thought and feeling of the nation, which it had never taken before. His marriage about the same time with Lady Augusta Bruce, contributed to make the Deanery from that time forth a centre of all that was intellectual, cultivated, and refined in English society, and at the same time a place where persons of any distinction, whatever their class, creed, or opinions, were equally welcome, and could meet on equal terms. He was elected F.R.S. in 1863, and in 1875 was chosen Lord Rector of the University of St. Andrew's. The first published work by which Dean Stanley was generally known, was his "Life and Letters of Dr. Arnold"—a work generally admitted to be almost without a rival in modern biography, both for the interest of its subject and the accomplished grace of its treatment. This has been followed by "Lectures on the Jewish

Church," in three volumes, "Lectures on the Eastern Church," numerous sermons and essays, "Historical Memorials of Canterbury and of Westminster," and "Sinai and Palestine," which contains the most vividly picturesque topographical, and historical descriptions of those countries to be found in the language, based on observations made in a journey to the East in 1852–53. The series of sermons which he deemed it part of his duty to preach in the Abbey on all occasions of national and historical interest, will, it is hoped, shortly be published in a collected form.

The wide-spread and enduring popularity of these numerous works is due not only to the intrinsic interest of the subjects chosen, and the brilliance, grace, and charm of the language in which they are written, but also in great measure to the spirit with which they are animated—a spirit which though it can be discerned through all he wrote, could only be fully appreciated by those who knew him personally, for his were, in the words of his successor to the Deanery, "the courage which never looked behind to see who followed as he sprang forward in the defence of anyone whom he deemed unfairly overborne by intolerance or injustice, the inexhaustible fund of tenderness that never failed his friends in the hour of distress, the indescribable gifts and graces that defied analysis which won him not only the undying love of those that knew him, but the hearts of multitudes who never saw him, the imagination, the genius, and the knowledge that cast such a flood of light on the persons, the places, the events, the scenes of so many stages of human history, the ardour that threw itself so keenly into all the interests of the present and all the problems of the future, the purity of heart that made men feel that they could not think of evil in his presence, the largeness of heart that tried so earnestly 'to knit the knots of peace and love throughout all Christian lands,' and the voice that year after year pleaded so eagerly for 'whatsoever things are lovely, whatsoever things are pure, whatsoever things are of good report.'"

Sir Philip de Malpas Grey Egerton, Bart., M.P., of Oulton Park, Cheshire, died at his London residence on the morning of April 1, 1881, after only a few days' illness. He was the eldest son of the Rev. Sir Philip Grey Egerton, the ninth baronet, and was born on November 13th, 1806. After passing his schooldays at Eton, he entered at Christ Church, Oxford, where he graduated in 1828. While still an undergraduate he exhibited a great taste for geology, and studied under Buckland and Conybeare; and it was at this time, in conjunction with his intimate friend and college companion, Lord Cole—now Earl of Enniskillen—that he devoted himself to the formation of a collection of fossil fish. Together with Lord Cole he travelled through Germany, Switzerland, and Italy for the purposes of study and collection; and in 1836 there appeared in the "Philosophical Magazine" a catalogue of the fossil fish in their joint collections, with references to the localities, geological positions, and published descriptions of the species. The ardour of the two collectors never ceased, and in 1841 a catalogue of fossil fish in the collections of the Earl of Enniskillen and Sir P. Grey Egerton was published in the "Annals of Natural History;" and in 1869 an alphabetical catalogue of the type specimens in Sir Philip's collection was printed in the "Geological Magazine." The two collections that thus went on side by side are undoubtedly the most complete that have ever been formed by private individuals, and mutually illustrate each other. That formed by the Earl of Enniskillen has fortunately been acquired by the Trustees of the British Museum, and there appears to be some prospect of Sir Philip Egerton's collection becoming also the property of the nation. The two series, in conjunction with the specimens already in the national collection, will probably render it unrivalled in the department of fossil Ichthyology.

Sir Philip was, however, not merely a collector, but a careful and scientific observer and a good naturalist. His memoirs on fossil fishes, for the most part contained in the publications of the Geological Society of London and in the "Decades of the Geological Survey," are upwards of seventy in number, and many of them of great importance. He was also the author of various papers on fossil reptiles, on ossiferous caves, and on other subjects.

He became a Fellow of the Geological Society in the year 1829, and was elected F.R.S. in February, 1831, having thus been a member of our body for upwards of fifty years. His memoir on "Chondrosteus, an Extinct Genus of the Sturionidæ found in the Lias Formation at Lyme Regis," was printed in the "Phil. Trans." for 1858. For his distinguished services in geological and palæontological science he received from the President and Council of the Geological Society the Wollaston Medal in 1873.

At the time of his death he was the senior elected Trustee of the British Museum, one of the original Trustees of the British Association for the Advancement of Science, a Trustee of the Royal College of Surgeons of London, and a member of the Senate of the University of London.

His public as well as his scientific services were great. He was a Deputy Lieutenant and a Justice of the Peace for Cheshire, and Lieutenant-Colonel of the Cheshire Yeomanry Cavalry. Either as Member of Parliament for the City of Chester or for the Southern or Western Divisions of Cheshire, he sat in the House of Commons from the year 1830, being of late the oldest member but one of that House.

Of a genial and kind disposition, of great business ability, and of good judgment and wide experience, Sir Philip Egerton was of great assistance at the meetings of any body of which he was a member, and his loss is deplored not only by the councils of more than one learned society but by a large circle of attached friends.

Professor Rolleston's death, which took place at Oxford on June 16, may well be called premature, as he was in the prime of life, and but a few months before seemed to all, except a few closely observant intimate associates, still in the plenitude of his powers, and capable of much good work in time to come.

The son of a Yorkshire clergyman, he was born at Maltby on July 30, 1829, and had therefore not completed his fifty-second year. His early aptitude for classical studies, carried on under the instruction of his father, must have been most remarkable if, as has been stated in one of his biographies, he was able at the age of ten to read any passage of Homer at sight. He was not educated at one of the great public schools, but entered at Pembroke College, Oxford, took a First Class in Classics in 1850, and was elected a Fellow of his College in 1851. He then studied medicine at St. Bartholomew's Hospital, joined the staff of the British Civil Hospital at Smyrna during the latter part of the Crimean War, was appointed assistant-physician to the Children's Hospital in London, 1857, but took up his residence again at Oxford in the same year on receiving the appointment of Lee's Reader in Anatomy at Christ Church. In 1860 he was elected to the newly-founded Linacre Professorship of Anatomy and Physiology, which he held to the time of his death. He was elected a Fellow of the Royal Society in 1862, and a Fellow of Merton College, Oxford, in 1872. He was a member of the Council of the University, and its representative in the General Medical Council, and also an active member of the Oxford Local Board.

In 1861 he married Grace, daughter of Dr. John Davy, F.R.S., and niece of Sir Humphry Davy, and he leaves a family of seven children.

The duties of the Linacre professorship involved the teaching of a wide range of subjects included under the terms of physiology and anatomy, human and comparative, to which he added the hitherto neglected but important subject of anthropology, as well as the care of a great and ever-growing museum. In the present condition of scientific knowledge it requires a man of very versatile intellect and extensive powers of reading to maintain anything like an adequate acquaintance with the current literature of any one of these subjects, much more to undertake original observations on his own account. Even a man of Rolleston's powers felt the impossibility of any one person doing justice to the chair as thus constituted, and strongly urged the necessity of dividing it into three professorships, one of physiology, one of comparative anatomy, and one of human anatomy and anthropology. The work which he did however contrive to find time to publish, and by which he will be chiefly known to posterity, is remarkable for its thoroughness. He never committed himself to writing without having completely mastered everything that had been previously written upon the subject, and his memoirs bristle with quotations from, and references to, authors of all ages and all nations. The abundance with which these were supplied by his wonderful memory, and the readiness with which, both in speaking and writing, his thoughts clothed themselves with appropriate words, sometimes made it difficult for ordinary minds to follow the train of his argument through long and voluminous sentences, often made up of parenthesis within parenthesis.

The work which was most especially the outcome of his professorial duties is the "Forms of Animal Life," published at the Clarendon Press in 1870. Though written chiefly with a view to the needs of the university students, it is capable of application to more general purposes, and is one of the earliest and most complete examples of instruction by the study of a series of types, now becoming so general. As he says in the preface, "The distinctive character of the book consists in its attempting so to combine the concrete facts of zootomy with the outlines of systematic classification, as to enable the student to put them for himself into their natural relations of foundation and superstructure. The foundation may be wider, and the superstructure may have its outlines not only filled up, but even considerably altered by subsequent and more extensive labours; but the mutual relations of the one as foundation and the other as superstructure which this book particularly aims at illustrating, must always remain the same."

Besides this work, Professor Rolleston's principal contributions to comparative anatomy and zoology are the following:—"On the Affinities of the Brain of the Orang Utang," "Nat. Hist. Review," 1861; "On the Aquiferous and Oviductal System in the Lamellibranchiate Molluscs" (with Mr. C. Robertson), "Phil. Trans.," 1862; "On the Placental Structures of the Tenrec (*Centetes ecaudatus*) and those of certain other Mammals, with Remarks on the Value of the Placental System of Classification," "Trans. Zool. Soc.," 1866; "On the Domestic Cats of Ancient and Modern Times," "Journal of Anatomy," 1868; "On the Homologies of Certain Muscles Connected with the Shoulder-Joint," "Trans. Linn. Soc.," 1870; "On the Development of the Enamel in the Teeth of Mammals," "Quart. Journ. Micros. Soc.," 1872; and "On the Domestic Pig in Prehistoric Times," "Trans. Linn. Soc.," 1877.

Latterly he did much admirable work in anthropology, for which he was excellently qualified, being one of the few men who possess the culture of the antiquary, historian, and philologist on the one hand, and of the anatomist and zoologist on the other, and could make these different branches of knowledge converge upon the complex problems of man's early history. The chief results of his work of this nature are contained in his contributions to Greenwell's "British Barrows" (1877), a book containing a fund of solid information relating to the early inhabitants of this island. His last publication, and one which is on the whole the most characteristic as exhibiting his vast range of knowledge on many different subjects, was a lecture delivered in 1879 at the Royal Geographical Society on "The Modifications of the External Aspects of Organic Nature produced by Man's Interference."

That Dr. Rolleston has not left more original scientific work behind him is easily accounted for by the circumstances under which he lived at Oxford. The multifarious nature of the subjects with which the chair was overweighted; the perpetual discussions in which during the whole term of his office he was engaged consequent upon the transitional condition of education, both at Oxford and elsewhere; the immense amount of business thrust upon him, or voluntarily undertaken by him, of the kind which always accumulates round the few men who are at the same time capable and unselfish, such as questions pertaining to the local and especially to the sanitary affairs of the town in which he lived, or questions connected with the reform of the medical profession, arising both within and outside the Medical Council, which latter business constantly brought him to meetings in London; his own wide grasp of interest in social subjects and deep feeling of the responsibilities of citizenship, and a sense of the duties of social hospitality, which made his house always open to scientific visitors to Oxford: all these rendered impossible to him that intense concentration which is requisite for carrying out any continuous line of research.

He was often blamed for undertaking so much and such diverse kinds of labour, so distracting to his scientific pursuits; but being by constitution a man who could never see a wrong without feeling a burning desire to set it right, who could never "pass by on the other side" when he felt that it was in his power to help, nothing but actual physical impossibility would restrain him. For several years past, when feeling that his health and strength did not respond to the strain he put upon them, he resorted to every hygienic measure suggested but one, and that the one he most required—rest; but this he never could or would take. During the last term he spent at Oxford, before his medical friends positively forced him (though unfortunately too late) to give up his occupations and seek change in a more genial climate, he was working at the highest pressure, rising every morning at six o'clock, to get two uninterrupted hours in which to write the revised edition of the "Forms of Animal Life" before the regular business of the day commenced.

It is impossible for those who had no personal knowledge of Rolleston to realise what sort of a man he was, and how great his loss will be to those who remain behind him. No one can ever have passed an hour in his company, or heard him speak at a public meeting, without feeling that he was a man of most unusual power, of lofty sentiments, generous impulses, marvellous energy, and wonderful command of language. In brilliant repartee, aptness of quotation, and ever-ready illustration from poetry, history, and the literature of many nations and many subjects, besides those with which he was especially occupied, he had few equals. "In God's war slackness is infamy" might well have been his motto, for with Rolleston there was no slackness in any cause which he believed to be God's war. He was impetuous, even vehement, in his advocacy of what appeared to him true and right, and unsparing in denunciation of all that was mean, base, and false. To those points in the faith of his fathers which he believed to be essential he held reverently and courageously, but on many questions both social and political, he was a reformer of the most advanced type. Often original in his views, always outspoken in giving expression to them, he occasionally met with the fate of those who do not swim with the stream, and was misunderstood; but this was more than compensated for by the affection, admiration, and enthusiasm with which he was regarded by those who were capable of appreciating his nobility of character. The loss of the example afforded by such a nature, and of his elevating influence upon younger and weaker men, is to our mind a still greater loss, both within and without the University in which he taught, than the loss of what scientific work he might yet have performed.

Dr. Rolleston's personal appearance corresponded with his character. Of commanding height, broad-shouldered, with a head of unusual size, indicating a volume of brain commensurate with his intellectual power, and with strongly-marked and expressive features, in which refinement and vigour were singularly blended, in him we saw just such a man as was described by the public orator at the late Oxford Commemoration, in words with which we may conclude this notice—"Virum excultissimi ingenii, integritatis incorruptissimæ, veritatis amicum, et propugnatorem impavidum."—W. H. F.

PROCEEDINGS

OF

THE ROYAL SOCIETY.

November 17, 1881.

THE PRESIDENT in the Chair.

In pursuance of the Statutes, notice of the ensuing Anniversary Meeting was given from the Chair.

Mr. Alfred Bray Kempe was admitted into the Society.

Professor W. G. Adams, General Boileau, General Clerk, Dr. Duncan, and Mr. R. H. Scott, having been nominated by the President, were elected by ballot Auditors of the Treasurer's Accounts on the part of the Society.

The Presents received were laid on the table, and thanks ordered for them.

A letter from the Foreign Office was read inclosing a despatch, dated September 1, 1881, from Major Wodehouse, Her Majesty's Consul at Honolulu, stating that the flow of the lava-stream from the volcano, Mauna Loa, had "finally ceased."

The following Papers were read:—

I. "Preliminary Note on the Photographic Spectrum of Comet *b* 1881. By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S. Received June 27, 1881.

[PLATE 1.]

On the evening of June 24, I directed the reflector furnished with the spectroscopic and photographic arrangements described in my paper "On the Photographic Spectra of Stars"* to the head of the comet, so that the nucleus should be upon one half of the slit. After one hour's exposure the open half of the slit was closed, the shutter

* "Phil. Trans.," 1880, p. 669.

withdrawn from the other half, and the instrument then directed to Arcturus for fifteen minutes.

After development, the plate presented a very distinct spectrum of the comet, together with the spectrum of the star, which I have already described in the paper referred to above.

The spectrum of the comet consists of a pair of bright lines in the ultra-violet region, and a continuous spectrum which can be traced from about F to some distance beyond H.

The bright lines, a little distance beyond H, with an approximate wave-length from 3870 to 3890, appear to belong to the spectrum of carbon (in some form, possibly in combination with hydrogen), which I observed in the spectra of the telescopic comets of 1866 and 1868.

In the continuous spectrum shown in the photograph, the dark lines of Fraunhofer can be seen.

This photographic evidence supports the results of my previous observations in the visible spectra of some telescopic comets. Part of the light from comets is reflected solar light, and another part is light of their own. The spectrum of this light shows the presence in the comet of carbon, possibly in combination with hydrogen.

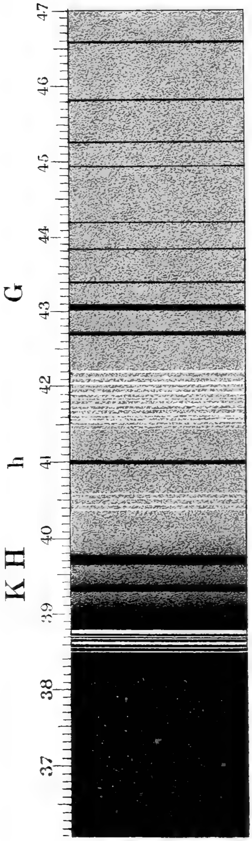
On the next night, June 25, a second photograph was obtained with an exposure of an hour and a half. This photograph, notwithstanding the longer exposure, is fainter, but shows distinctly the two bright lines and the continuous spectrum, which is too faint to allow the Fraunhofer lines to be seen.

(Postscript, July 9, 1881.)

I have since measured the photographs of the comet's spectrum, and I find for the two strong bright lines the wave-lengths 3883 and 3870. The less refrangible line is much stronger, and a faint luminosity can be traced from it to a little beyond the second line 3870. There can be, therefore, no doubt that these lines represent the brightest end of the ultra-violet group which appears under certain circumstances in the spectra of the compounds of carbon. Professors Liveing and Dewar have found for the strong line at the beginning of this group the wave-length 3882·7, and for the second line 3870·5.

I am also able to see upon the continuous solar spectrum, a distinct impression of the group of lines between G and *h*, which is usually associated with the group described above. My measures for the less refrangible end of this group give a wave-length of 4230, which agrees as well as can be expected with Professors Liveing and Dewar's measure 4220.

In their paper "On the Spectra of the Compounds of Carbon," "Proc. Roy. Soc.," vol. 30, p. 494, Professors Liveing and Dewar show that these two groups indicate the presence of cyanogen, and



Spottiswoode & Co. Lith. London.

are not to be seen in the absence of nitrogen. If this be the case, the photograph gives undoubted evidence of the presence of nitrogen in the comet, in addition to the carbon and hydrogen shown to be there by the bright groups in the visible part of the spectrum. On this hypothesis we must further suppose a high temperature in the comet unless the cyanogen is present ready formed.

I should state that Mr. Lockyer regards the two groups in the photograph, and the groups in the visible spectrum, to be due to the vapour of carbon at different heat-levels ("Proc. Roy. Soc." vol. 30, p. 461).

It is of importance to mention the strong intensity in the photograph of the lines 3883 and 3870, as compared with the continuous spectrum, and the faint bright group beginning at 4230. At this part of the spectrum, therefore, the light emitted by the cometary matter exceeded by many times the reflected solar light. I reserve for the present the theoretical suggestions which arise from the new information which the photographs have given us.

The diagram shows the two sets of bright lines and the solar spectrum. There is also indicated in it a small increase of brightness between *h* and H, which was suspected in the photograph.

[The accompanying lithograph was executed by order of the British Association for the Advancement of Science, for the illustration of the forthcoming Report for 1881. The use of the stone has been allowed to the Royal Society by the Council of the Association.—G. G. Stokes, Sec. R.S.]

II. "Note on the Reversal of the Spectrum of Cyanogen." By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received July 4, 1881.

In the course of many observations on the reversal of lines of metallic spectra, we have frequently noticed dark shaded bands which appeared to be the reversals of bands ascribed to the oxides or chlorides of sundry metals ; more particularly we have seen them when experimenting with compounds of the alkaline earths, and we have repeatedly obtained a reversal of the green magnesium-hydrogen series ; but, until recently, we have never seen any reversal of the shaded bands of the spectrum of cyanogen, though our attention has been constantly directed to this spectrum. Quite lately, however, we have obtained photographs which show the reversal of the violet and ultra-violet bands of this spectrum ; and the fact is perhaps of sufficient interest, especially in connexion with the question of the occurrence of these bands amongst the Fraunhofer lines, to warrant the publication of this note. We have not yet succeeded in determining precisely the conditions under which the reversal can be produced at will. The most complete reversals of these bands were obtained by the use of the arc of a Siemens' machine, in a crucible of magnesia, fed with a considerable quantity of cyanide of titanium. The photographs in this case show a very complete reversal of the five bands near L, and of the two strong bands near N, and a less complete reversal of the six bands, beginning at about wave-length 4215. No other metallic cyanides have given, when introduced into the crucible, any such reversal; nor does a stream of cyanogen led in through a perforated carbon produce the effect. Various other nitrogenous compounds have been tried, but the only one which has given us anything like the effect of the titanic cyanide is borate of ammonia. Some photographs taken immediately after the introduction of borate of ammonia show distinctly the reversal of the group of bands near L. In one case when metallic magnesium had been put into the crucible, the photograph shows a reversal of only that part of the series which is nearest to the magnesium group, indicating that the reversal is due to the bright background supplied by the expanded magnesium lines. There can be little doubt that the greater stability of titanic cyanide and boron nitride than of other nitrogenous compounds, has some influence upon the result; and the difficulty in producing the reversal at will is in securing an absorbent stratum of sufficiently high temperature and at the same time a sufficiently luminous background. The circumstances which secure the former condition almost always produce in the arc a still more intense radiation of just those rays which are absorbed, without that expansion of the lines which shows out the absorption in the case of so many metallic spectra. The photographs are, however, conclusive evidence that it is possible to secure both conditions.

III. "The Sums of the Series of the Reciprocals of the Prime Numbers and of their Powers." By C. W. MERRIFIELD, F.R.S. Received August 8, 1881.

Euler has shown* that it is possible to sum the series of reciprocals of powers of the prime numbers, and he has calculated the values of these sums for the even powers. I thought it of some interest to calculate the sums for the odd powers, and to evaluate a peculiar constant (somewhat analogous to the Eulerian constant,—

$$\gamma=0{\cdot}57721\quad 56649\quad 01532\quad 86060\quad 65)$$

* "Introd. in Anal. Infin.," vol. i, cap. xv, "De seriebus ex evolutione factorum ortis," pp. 221–252.

which presents itself, in the series of simple reciprocals of primes, as the difference between the sum of the series and the double logarithmic infinity to the Napierian base ϵ.

The summation of these series was shown by Euler to depend upon the Napierian logarithms of the sums of the reciprocals of the powers of the natural numbers. Euler's reason for taking even powers only was doubtless that these latter summations could be expressed in terms of Bernoulli's numbers, and of the powers of π, and could therefore be computed directly, without any actual summation. A table given by Legendre,* and reprinted by De Morgan,† however, contains the whole series of the sums of the reciprocals of the powers of the natural numbers, even as well as odd, and I have made use of this table as the basis of my own work, being satisfied with the verifications of Legendre.

The first step was to find the Napierian logarithms of all the numbers given in Legendre's table. These were then combined, so as to give the summations of primes, by means of a theorem of Möbius‡ used by Mr. J. W. L. Glaisher,§ in calculating a corrected table of Euler's values. Instead of giving my own results only, I have thought it would be convenient to bring together the complete set ‖ of—

1. Legendre's table of the sums of the reciprocals of the powers of the natural numbers, to 16 figures.

2. The Napierian logarithms of the numbers in that table, to 15 figures.

3. The whole series of the sums of the reciprocals of the powers of primes, to 15 figures.

I think it will be convenient also to give a very short note of the means of obtaining the results, as the best explanation which they can receive, and as saving some troublesome references to books not accessible to everybody.

Since the reciprocal of $1-\frac{1}{x}$ is the geometrical progression—

$$1+\frac{1}{x}+\frac{1}{x^2}+\frac{1}{x^3}+\ \ldots\ ;$$

* "Traité des Fonctions Elliptiques," vol. ii, p. 432.

† See his "Diff. and Int. Calc.," p. 554.

‡ Crelle's "Journal," vol. ix, p. 105.

§ See the "Transactions" of the "Association Française pour l'Avancement des Sciences," Havre, 1877.

‖ See Mr. J. W. L. Glaisher's paper in the "London Mathematical Society's Proceedings," vol. iv (for 1872), pp. 48–56, "On the Constants that occur in certain Summations by Bernoulli's Series," for the summations of some allied series, namely—

$$1^{-n}-2^{-n}+3^{-n}-4^{-n}+\ \ldots\ (\textit{natural numbers}),$$

$$\text{and } 1^{-n}+3^{-n}+5^{-n}+7^{-n}+\ \ldots\ (\textit{odd numbers}).$$

by giving x every prime value, and multiplying all the fractions on one side of the equations into one another, and all the progressions on the other side into one another, we have—

$$(1-\tfrac{1}{2})^{-1}(1-\tfrac{1}{3})^{-1}(1-\tfrac{1}{5})^{-1}\ \ldots\ (\textit{primes})$$
$$=1+\tfrac{1}{2}+\tfrac{1}{3}+\tfrac{1}{4}+\tfrac{1}{5}+\tfrac{1}{6}+\ \ldots\ (\textit{natural numbers}).$$

For the multiplication of the progressions brings together once, and once only, all the factors which make up each term of the harmonic series. Moreover, this is true, not only of the simple numbers, but of any powers, so that generally—

$$(1-2^{-n})^{-1}(1-3^{-n})^{-1}(1-5^{-n})^{-1}\ \ldots\ (\textit{primes})$$
$$=1+2^{-n}+3^{-n}+4^{-n}+\ \ldots\ (\textit{natural numbers}).$$

If n has any positive integral value except unity, the second side of this equation is always finite. When $n=1$, it may be transformed (as is well known) into—

$$\log_\epsilon x+\gamma+\frac{1}{2x}-\frac{1}{12x^2}+\frac{1}{120x^4}-\ \ldots\ .$$

Calling the series of the reciprocal n^{th} powers of the natural numbers S_n, and of the primes Σ_n, we have, upon taking the logarithms,—

$$lS_n=\Sigma_n+\tfrac{1}{2}\Sigma_{2n}+\tfrac{1}{3}\Sigma_{3n}+\tfrac{1}{4}\Sigma_{4n}+\ \ldots\ .$$

This would enable us to obtain the value of lS, if we knew the series Σ. The theorem of Möbius, mentioned above, enables us to effect the reversal of this, and to obtain Σ in terms of lS. This theorem, which is easily established inductively by indeterminate coefficients, is as follows: let—

$$F(x)=f(x)+\tfrac{1}{2}f(x^2)+\tfrac{1}{3}f(x^3)+\tfrac{1}{4}f(x^4)+\ \ldots\ .$$

then

$$f(x)=F(x)-\tfrac{1}{2}F(x^2)-\tfrac{1}{3}F(x^3)-\tfrac{1}{5}F(x^5)+\tfrac{1}{6}F(x^6)-\tfrac{1}{7}F(x^7)+\tfrac{1}{10}F(x^{10})-\ \ldots\ .$$

the law of the last series being that every term whose index contains a square factor disappears, the others being positive or negative accordingly as the index contains an even or odd number of prime factors. Thus $F(x^4)$, $F(x^8)$, $F(x^9)$, $F(x^{12})$ all take the coefficient zero, while $F(x^6)$ and $F(x^{10})$ are positive; but all the prime terms, and such terms as $F(x^{30})$, $F(x^{42})$, &c., are negative. This at once gives—

$$\Sigma_n=lS_n-\tfrac{1}{2}lS_{2n}-\tfrac{1}{3}lS_{3n}-\tfrac{1}{5}lS_{4n}+\tfrac{1}{6}lS_{6n}-\tfrac{1}{7}lS_{7n}+\tfrac{1}{10}lS_{10n}-\ \ldots\ .$$

This is the formula given by Mr. Glaisher, and used both by him and by myself in the calculation of Σ_n.

In the particular case of $n=1$, we have—

$$\Sigma_1 = \log(\log x) - 0{\cdot}31571\ \ 84520\ \ 73890\quad [x=\infty].^*$$

I have not been able to identify this constant 0·3157 .... with any function of a known constant. It does not seem to have any immediate connexion with the Eulerian constant γ; for

$$\log_\epsilon \gamma = -0{\cdot}5496, \qquad \gamma^2 = 0{\cdot}33316.$$

There appears no reason why it should be commensurable with any simple function of γ. The following results may be useful for the purpose of this or analogous comparisons:—

$$\epsilon^{\gamma} = 1{\cdot}781072, \qquad \epsilon^{-\gamma} = 0{\cdot}5614595,$$

$$\epsilon^{-\Sigma_1} = 1{\cdot}371241,\dagger \qquad \epsilon^{\Sigma_1} = 0{\cdot}7292647,\dagger$$

$$\epsilon^{(1+\Sigma_1)} = 1{\cdot}982347,\dagger \qquad \epsilon^{-(1+\Sigma_1)} = 0{\cdot}5044525.\dagger$$

It is worth while to remark that the S series $1+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}+\ldots\ldots$ begins with unity, whereas the prime series $\frac{1}{2}+\frac{1}{3}+\frac{1}{5}+\ldots\ldots$ begins with $\frac{1}{2}$, and omits the unit.

The last two tables are given to 15 decimal places, having been calculated to 16 places. Still, the last figure is not reliable. The tables are not continued to very high values of n, because, for such values—

$$S_n - 1 = \log(S_n) = \Sigma_n$$

$$= 2(S_{n-1} - 1) = 2\log(S_{n-1}) = 2\Sigma_{n-1},$$

true to 15 decimal places, or more.

* There may be some doubt as to the correctness of this expression. This turns on whether the assumption which it involves is justifiable, namely—

$$\log\left\{S(x)^{-1}\right\} - \log(\log x) = 0$$

when $x=\infty$, and consequently when both terms on the first side of the equation represent divergent series. This, however, is not a question which much affects the arithmetic.

† Omitting the term log (log ∞).

Table of the Sums of the Powers of the Reciprocals of the Natural Numbers, $S(\infty)^{-n}$, to 16 Decimal Figures, from Legendre.

n.		$S(\infty)^{-n}$.			
1	....	$\begin{cases} \log(\infty) + \\ 0 \cdot 57721 \end{cases}$	56649	01532	9
2	....	1·64493	40668	48226	4
3	....	1·20205	69031	59594	3
4	....	1·08232	32337	11138	2
5	....	1·03692	77551	43370	0
6	....	1·01734	30619	84449	1
7	....	1·00834	92773	81922	7
8	....	1·00407	73561	97944	3
9	....	1·00200	83928	26082	2
10	....	1·00099	45751	27818	0
11	....	1·00049	41886	04119	4
12	....	1·00024	60865	53308	0
13	....	1·00012	27133	47578	5
14	....	1·00006	12481	35058	7
15	....	1·00003	05882	36307	0
16	....	1·00001	52822	59408	6
17	....	1·00000	76371	97637	9
18	....	1·00000	38172	93265	0
19	....	1·00000	19082	12716	6
20	....	1·00000	09539	62033	9
21	....	1·00000	04769	32986	8
22	....	1·00000	02384	50502	7
23	....	1·00000	01192	19926	0
24	....	1·00000	00596	08189	1
25	....	1·00000	00298	03503	5
26	....	1·00000	00149	01554	8
27	....	1·00000	00074	50711	8
28	....	1·00000	00037	25334	0
29	....	1·00000	00018	62659	7
30	....	1·00000	00009	31327	4
31	....	1·00000	00004	65662	9
32	....	1·00000	00002	32831	2
33	....	1·00000	00001	16415	5
34	....	1·00000	00000	58207	7
35	....	1·00000	00000	29103	8

Table of the Napierian Logarithms of the Sums of the Powers of the Reciprocals of the Natural Numbers, $\log_\epsilon S(\infty)^{-n}$, to 15 Decimal Figures.

n.		$\log_\epsilon S(\infty)^{-n}$.		
1	....	log (log ∞)		
2	....	0·49770	03024	70745
3	....	0·18403	41753	91491
4	....	0·07910	98730	67336
5	....	0·03626	22596	49228
6	....	0·01719	43876	02658
7	....	0·00831	46149	69275
8	....	0·00406	90663	07413
9	....	0·00200	63787	01528
10	....	0·00099	40808	65669
11	....	0·00049	40665	33147
12	....	0·00024	60562	78979
13	....	0·00012	27058	18911
14	....	0·00006	12462	59468
15	....	0·00003	05877	68496
16	....	0·00001	52821	42636
17	....	0·00000	76371	68475
18	....	0·00000	38172	85979
19	....	0·00000	19082	10896
20	....	0·00000	09539	61579
21	....	0·00000	04769	32873
22	....	0·00000	02384	50474
23	....	0·00000	01192	19919
24	....	0·00000	00596	08187
25	....	0·00000	00298	03503
26	....	0·00000	00149	01555
27	....	0·00000	00074	50712
28	....	0·00000	00037	25334
29	....	0·00000	00018	62660
30	....	0·00000	00009	31327
31	....	0·00000	00004	65663
32	....	0·00000	00002	32831
33	....	0·00000	00001	16416
34	....	0·00000	00000	58208

Table of the Sums of the Powers of the Reciprocals of the Prime Numbers $\Sigma(x)^{-n}$, x Prime, and taken from 2 to ∞; to 15 Decimal Figures.

n.		$\Sigma_2^\infty (x)^{-n}$.		
1	......	{ log (log ∞)		
		−0 31571	84520	73890
2	......	+0 ·45224	74200	41065
3	....	0 ·17096	26392	99444
4	....	0 ·07699	31397	64247
5	....	0 ·03575	50164	83924
6	....	0 ·01707	00868	50637
7	....	0 ·00828	38328	56134
8	....	0 ·00406	14053	66518
9	....	0 ·00200	44675	74962
10	....	0 ·00099	36035	74437
11	....	0 ·00049	39472	69104
12	....	0 ·00024	60264	70035
13	....	0 ·00012	26973	67528
14	....	0 ·00006	12443	96725
15	....	0 ·00003	05873	02823
16	....	0 ·00001	52820	26219
17	....	0. 00000	76371	39371
18	....	0 ·00000	38172	78703
19	....	0 ·00000	19082	09077
20	....	0 ·00000	09539	61124
21	....	0 ·00000	04769	32759
22	....	0 ·00000	02384	50446
23	....	0 ·00000	01192	19912
24	....	0 ·00000	00596	08185
25	....	0 ·00000	00298	03503
26	....	0 ·00000	00149	01555
27	....	0 ·00000	00074	50712
28	....	0 ·00000	00037	25334
29	....	0 ·00000	00018	62660
30	....	0 ·00000	00009	31327
31	....	0 ·00000	00004	65663
32	....	0 ·00000	00002	32831
33	....	0 ·00000	00001	16416
34	....	0 ·00000	00000	58208
35	....	0 ·00000	00000	29104

IV. "Further Note on the Minute Anatomy of the Thymus." By Herbert Watney, M.A., M.D. Cantab. Communicated by E. A. Schäfer, F.R.S. Received August 26, 1881.

Ciliated epithelial cells are found in the thymus of the dog: this is not the case in quite young animals, but ciliated epithelium can always be demonstrated in the thymus of a dog over thirty months old, and often in those of much younger animals. In the older dogs the ciliated cells are found lining cysts, and the cysts appear to increase in size with the age of the animal. The ciliated epithelial cells take origin from connective tissue corpuscles. The connective tissue corpuscles forming the network in the medullary portion are in places massed together, forming concentric corpuscles of small size; in these masses small cavities are formed, and the lining cells are transformed into ciliated cells.

In the thymus of the tortoise small cavities are found lined by columnar epithelium. The epithelial cells arise from connective tissue corpuscles, the process being essentially the same as that just described in the dog.

The fluid in the lymphatic vessels leading from the thymus can be obtained by tying the vessels immediately after death. The lymph thus obtained contains considerably more colourless corpuscles than the lymph of the large lymphatic vessels of the neck. The blood in the veins passing from the thymus does not appear to differ from the blood of the jugular vein.

V. "Experimental Researches on the Propagation of Heat by Conduction in Bone, Brain-tissue, and Skin." By J. S. Lombard, M.D., formerly Assistant Professor of Physiology in Harvard University. Communicated by Dr. Brown-Séquard, F.R.S. Received October 1, 1881.

(Abstract.)

The experiments (over 900 in number) were made on the skull and long bones of sheep, the ribs of oxen, and on the brain and skin of sheep. Thermo-electric apparatus was employed in the work.

The different tissues were thus prepared:—In the case of bone, a fresh piece was ground smooth on one side, and the face of the thermopile accurately fitted to it; then a thin coating of shellac varnish was applied to the surface of the bone and to the face of the pile, and firm pressure was maintained until the varnish was dry and permanent

adhesion between the bone and the pile had taken place. The whole pile, and the bone, to within a couple of millimetres of its free surface, was then wrapped in thick layers of cotton wool soaked in melted paraffine, these layers extending beyond the upper end of the pile and along the conducting wires for a little distance. In the cases of brain-tissue and skin, a pasteboard box was taken and filled with melted paraffine. When the latter had solidified, a hole was cut through the centre of the paraffine of the size of the piece of brain or skin, and the pasteboard bottom corresponding to the hole removed, and its place supplied by a thin copper plate. The piece of tissue was then inserted in the hole in the paraffine, until it rested on the copper plate; the pile was then passed into the hole and pressed firmly upon the piece of brain or skin, being kept in place by wedges of cotton wool thrust between the sides of the pile and the paraffine walls surrounding it.

The free end of the bone, or the copper plate of the box,* was brought in contact with water of the desired temperature, this temperature being tested by both thermo-electric apparatus and thermometers.

The differences of temperature to which the tissues were subjected ranged from 0°·1136 C. to 0°·1645 C.

We have to consider, first, the time required for the *first sign* of the change of temperature to show itself through the pieces of bone, brain, and skin. The following figures show the times required for 0°·1 C. to show itself through 7·5 millims. of sheep's skull, 7·5 millims. of upper surface of sheep's cerebrum, and 3 millims. of sheep's scalp respectively.

The galvanometer shows 0°·0006742 C.—

	Bone.	Brain.	Scalp.
Averages............	37 ·30 seconds.	40 ·490 seconds.	22 ·880 seconds.
Maxima.............	55 ·86 ,,	63 ·706 ,,	29 ·417 ,,
Minima.............	26 ·29 ,,	27 ·646 ,,	10 ·000 ,,

We have next to consider the degree of change of temperature produced by conduction, at certain measured intervals of time, through the same thicknesses of tissues as above, and calculated for 0·1° C., with the galvanometer showing, as before, 0°·0006742 C. The averages alone are given.

* It was found, by many experiments, that the presence of the copper plate could be disregarded. The same is true of the dura mater in the case of brain-tissue.

Average effects of 0°·1 C.

Time from the moment of contact of free surface of bone or copper plate of paraffine box with the water.	Skull. 7·5 millims. thick.		Brain. 7·5 millims. thick.		Scalp. 3 millims. thick.	
	Degrees of galvanometer.	Thermometric values.	Degrees of galvanometer.	Thermometric values.	Degrees of galvanometer.	Thermometric values.
At the end of—						
1 min. 15 sec.	23·864°	0·01609° C.	21·036°	0·01418° C.	17·191°	0·01159° C.
2 " 0 "	54·170	0 03652	42·721	0·02880	31·241	0·02106
4 " 0 "	88·804	0·05987	74·840	0·05045	59·208	0 03992
6 " 0 "	116·476	0·07853	99·075	0·06679	80·766	0·05445

It will be seen that at the above periods the bone is the best conductor, the brain coming next, and the skin last, although the latter is 2·5 times thinner than the two former.

We have, in the third place, to see what is the transmission of heat through the three tissues, when the *permanent thermal condition* is reached. The following figures show the amounts of this transmission at the period in question.

Average effects of 0°·1 C. at permanent thermal period, through 7·5 millims. of skull, 7·5 millims. of cerebrum, and 3 millims. of scalp, respectively.

	Degrees of galvanometer.	Thermometric values.	Percentages of heat transmitted.
Skull.............	127 ·431°	0 ·08591° C.	85 ·918 per cent.
Brain	113 ·029	0 ·07620	76 ·208 "
Scalp.............	100 ·155	0 ·06751	67 ·514 "

Here again the bone shows the highest, and the skin the lowest, conductivity.

Suppose, now, that we have a change of temperature of 0°·1 C. at the surface of the brain of a sheep. As a matter of simple conduction, what would be the change of temperature at the outer surface, after the passage through the thicknesses of skull and scalp given? We will give the averages for two minutes and for the permanent thermal state only.

Average effects of 0°·1 C. through 7·5 millims. of sheep's skull and 3 millims. of sheep's scalp, taken together.

	Degrees of galvanometer.	Thermometric values.	Percentages of heat transmitted.
At the end of 2 minutes..	11·409°	0·007692° C.	7·692 per cent.
When the permanent thermal state was reached..	86·033	0·058006	58·006 ,,

Lastly, we will calculate what effect a change of temperature of 0°·1 C., at one point of the cerebral surface, would have on a point of the outer surface of the scalp situated over another point of brain surface distant 7·5 millims. from the point where the change of temperature occurs. We have, in this inquiry, first, to take the alteration of temperature produced by transmission through 7·5 millims. of brain-tissue (pages 12 and 13), and then to calculate how much of this heat would find its way through the 7·5 millims. of skull and the 3 millims. of scalp (see page 13).

Average effects of 0°·1 C. on the outer surface of the head after first passing through 7·5 millims. of brain-tissue.

	Degrees of galvanometer.	Thermometric values.	Percentages of heat transmitted.
At the end of 2 minutes..	4·873°	0·003286° C.	3·286 per cent.
When the permanent thermal state was reached..	65·563	0·044202	44·202 ,,

If we compare the above figures with those previously given as the results of the *direct* transmission from the point of the brain-tissue, the temperature of which is altered 0°·1 C.,* it is easy enough to see that, with the apparatus we are employing, the temperature of a point of the outer surface distant 7·5 millims. from a point lying directly over the focus of change would present differences very easy of detection.

The following figures show the excess of the *direct* over the *indirect* transmission.

* See page 13.

Average excess in favour of *direct* transmission.

	Degrees of galvanometer.	Thermometric values.
At the end of 2 minutes	6·536°	0·004402° C.
When permanent thermal condition was reached	20·470	0·013804

Unfortunately the tissues with which we are dealing obey no physical law with which the writer is acquainted, as regards the effect of changes of thickness of the conductor. It is, therefore, impossible to reason with accuracy from one thickness to another. The effect of the circulation of the blood in the head on the outward transmission of heat from the brain, has been somewhat fully considered by the writer elsewhere.*

VI. "On the Comparative Structure of the Brain in Rodents." By W. Bevan Lewis, L.R.C.P. (Lond.), Senior Assistant Medical Officer to the West Riding Asylum, Wakefield. Communicated by Dr. Ferrier, F.R.S., Professor of Forensic Medicine, King's College, London. Received October 13, 1881.

(Abstract.)

I have endeavoured in this abstract to summarise the results of my recent researches into the minute structure of the brain in the smaller Rodents. The pig and sheep, which were the subjects of my former memoir, possess a highly developed olfactory apparatus conjoined to a well convoluted cortical surface; but in the smaller animals now under consideration the surface of the hemispheres is almost perfectly smooth, while the olfactory organ, from its comparative size and complex relationship, has an important part to play in the architecture of the brain.

Animals possessing the latter type of cerebrum have been classed together as the Osmatic Lissencéphales, in contradistinction to those which were the subject of my former enquiries, the Osmatic Gyrencéphales. My researches into the structure of the brain of prominent members of the former group, viz., the rabbit and rat, may be considered under two heads:—

(*a.*) The histology of the complete cortical envelope.

* "Regional Temperature of the Head." London, 1879.

(*b.*) The central projections of the olfactory organ.

The cortex of the cerebrum of the rabbit and rat is naturally divisible into two distinct segments, which (to follow the nomenclature advocated by Broca) may be termed the great limbic lobe and extra-limbic mass or parietal segment. The great limbic lobe is further divisible into—

(*a.*) An upper limbic arc (gyrus fornicatus).

(*b.*) A lower limbic arc (gyrus hippocampi).

(*c.*) An anterior limbic arc (olfactory lobe).

Minute examinations of these regions reveal the presence of *eight diverse types of cortex*, which are distinguished from each other by the *number* or *kind* of the constituent layers. Meynert enumerates only five types as distinguishable in the cortex of human brain; and since his Sylvian type differs in degree rather than in kind, and should be therefore eliminated, we find in the small brain of the Rodent where frontal, temporal, and occipital lobes are absent, a greater variety of cortical constitution than what Meynert assigns to man. Meynert's enumeration, however, falls far short of the truth, since all the types found in the hemispheres of these lower animals prevail also in human brain, which therefore would embrace, at the very least, *ten* distinct types of cortical lamination.

The eight formations occurring in the rabbit and rat are as follows:—

1. Type of upper limbic arc.
2. Modified upper limbic type.
3. Outer olfactory type.
4. Inner olfactory type.
5. Modified lower limbic type.
6. Extra-limbic type.
7. Type of cornu ammonis.
8. Type of olfactory bulb.

The first six may be best summarised by noting the area covered by each, and the special feature bestowing upon each its typical character.

1. *Type of Upper Limbic Arc.*—Area. This cortex covers the whole anterior two-thirds of the upper limbic arc, reaching from frontal pole to near the posterior border of the corpus callosum. In front of the corpus callosum it spreads outwards over the exposed vertex, spanning the frontal end of the hemisphere here.—Type. A four laminated cortex, as follows:—1. A peripheral cortical zone. 2. Layer of small pyramidal cells. 3. Ganglionic cell layer. 4. Layer of spindle cells. The angular cells forming the second layer in human brain are here absent. The ganglionic formation is clearly identified with that of higher animals. Like the latter, they are arranged in clustered groups or solitary file, and are subject to the interposition betwixt them and the small pyramids of a layer of angular or granule cells in

certain regions. These cells are largest and most richly grouped along the upper limbic arc and the sagittal border, the layer here attaining a depth equal to that of the similar formation in the pig. These confluent groups are so rich in cells as to exhibit from eighty to one hundred in the quarter-inch field of the microscope, whilst the solitary arrangement will not show more than six or eight such cells in the same area. These cells are of elongate pyramidal form, the largest measuring $32\mu \times 18\mu$, but they maintain great uniformity in size.

2. *Modified Upper Limbic Type.*—Area. Commencing near the posterior border of the callosal commissure, this cortex spreads over the median aspect of the hemisphere as far as the occipital pole and the junction betwixt upper and lower limbic arcs, and also outwards over the exposed aspect of the hemisphere, ending abruptly at the primary parietal sulcus.—Type. It is four-laminated, the small pyramidal cells of the former type gradually thinning off and disappearing ultimately to be replaced by a deep belt of granule cells disposed in horizontal layers separated by alternate bands of arcuate medulla.

3. *Outer Olfactory Type.*—Area. Spreads over the anterior limbic arc betwixt the limbic sulcus and the superficial olfactory fasciculus. Thence it covers the whole of the gyrus hippocampi, except a limited area at the occipital end of the lower limbic arc.—Type. This is a three-laminated cortex, possessing only two layers of nerve-cells. It is constituted of—1. A peripheral cortical zone. 2. A belt of densely compressed irregular small pyramidal cells. 3. A layer of large pyramids.

4. *Inner Olfactory Type.*—Area. This cortex covers the "olfactory field" of Gratiolet, *i.e.*, the anterior perforated space. It is limited externally by the "outer root" of the olfactory lobe, and extends inwards to the median aspect of the hemisphere.—Type. A three-laminated cortex, consisting of—1. A peripheral cortical zone. 2. A peculiar wavy layer of granule cells. 3. Large spindle cells, with an arcuate medulla apparently connected with the claustral formation externally. The spindle cells attain unusual magnitude.

5. *Modified Lower Limbic Type.*—Area. Covers the extreme terminal portion of the limbic arc, and is bounded externally by the limbic sulcus and internally by the vanishing granule formation of the upper limbic cortex.—Type. A five-laminated cortex especially distinguished by its second layer of nerve-cells which are remarkably large, swollen, and irregular, and in fact the largest elements in the whole hemisphere. They strongly suggest in their form and branching an unusually rich development of the angular cell of the second layer in human brain, the elements of which, if greatly increased in size, would closely resemble these cells. This cortex also includes two notable arcuate bands of medulla.

6. *Extra-limbic Type.*—Area. This cortex covers the whole of the extra-limbic or parietal mass, except that portion already referred to as possessing the upper and modified limbic types.—Type. It is distinctly five laminated, viz.:—1. A peripheral zone; 2. Layer of small pyramids; 3. Belt of granule cells; 4. Ganglionic cells; 5. Spindle cells. It differs from the upper limbic type in the possession of a belt of granule cells, and in the peculiar disposition of its ganglionic cells which lose the clustered and assume a solitary arrangement.

The ganglionic cells become more and more numerous and thickly grouped towards the frontal pole, diminishing in numbers rapidly backwards, the granule cells being a more notable feature towards the occipital pole.

Significance of Sulci and Fissures.—In my former memoir I stated that certain sulci and fissures accurately mapped out structurally differentiated realms of the cortex. My further examination of the brain of the rat and rabbit enables me to state that at least *seven sulci and fissures* may now be accepted as the undoubted boundaries of adjacent realms *which wholly differ from each other in structure.* These are as follows:—

1. The limbic fissure.
2. The infra-parietal sulcus.
3. The primary parietal sulcus.
4. The inter-parietal sulcus.
5. The crucial sulcus.
6. The olfactory sulcus.
7. Fissure of Rolando.

Distribution of Ganglionic Formation.—The cortex, which is specially characterised by a rich deep belt of ganglionic cells in close confluent groups, spreads over that portion of the upper limbic arc immediately in front of the corpus callosum. Still richer in constituent elements, towards the marginal or sagittal border of the hemisphere it covers the exposed aspect here, being well developed over the three areas mapped out by Ferrier as the centres for the movements of the mouth and jaws (7); of the tongue (9); and of the shoulder and foreleg (5).

Along the sagittal border of the hemisphere at the vertex these rich cell groupings tend to spread backwards, but thin out rapidly as they approach the granule formation internal to the primary parietal sulcus.

The same tendency to extension of these ganglionic groups backwards is also seen along the Sylvian border of the hemisphere, *i.e.*, along the limbic sulcus.

I have therefore termed these groupings the Sagittal and Sylvian groups of the ganglionic formation.

In my former memoir I particularised the same features as noticeable in the brain of the sheep and pig, viz., the existence of an extensive area of the five-laminated rich ganglionic cortex in the anterior regions of the hemisphere with two projecting arms of a similar formation extending backwards. These latter—the Sagittal and Sylvian groups—embrace betwixt them an intermediate region of the parietal lobe characterised by a six-laminated cortex with solitary arrangement of the ganglionic cells which are few and poorly developed.

Central Projections of Olfactory Medulla.—The medullary connexions between the olfactory bulb and lobe and the cortex of the rest of the cerebrum consist of the following series:—

1. A central decussating and commissural fasciculus.
2. Medullated connexion with striate body.
3. Arciform medulla to limbic lobe and occipital pole.
4. Superficial olfactory fasciculus, the so-called "outer olfactory root."

1. *Central Olfactory Fasciculus.*—Of the various medullated connexions of the olfactory organ this exhibits the most interesting and novel features. After passing back from the olfactory bulb to its decussation in the anterior commissure, its posterior projections traverse the substance of the corpus striatum, and in this course its strands are widely separated by the passage through them of numerous fasciculi of medullated fibres which, arising behind run forwards, some blending with the other fibres of the olfactory fasciculus, but most traversing its structure at right angles so as to emerge in front of it as a delicate fibrous dissepiment betwixt the corpus striatum proper and that portion lying in the olfactory area. The posterior projection of the central fasciculus upon reaching the outer boundary of the striate body takes a different course in the rat and the rabbit. In the former it divides here into numerous secondary branches which are directed backwards towards the occipital pole of the hemisphere to *be distributed to the cortex described here as of the modified lower limbic type.* A limited number of fibres pass outside the striate body. In the rabbit, on the other hand, this fasciculus turns upwards upon the outer surface of the corpus striatum, and reaching the upper pole of this ganglion suddenly divides into a brush-like head of fibres, which decussating and interweaving with the callosal and projection systems here eventually *terminate in the cortex of the vertex at its marginal angle* (along the great longitudinal fissure).

2. *Connexions with Striate Body.*—Medullated bundles pass from the medulla of the olfactory lobe and the granule layer of the bulb backwards into the basal portion of the caudate nucleus separated from each other in this region by oblong grey masses which enclose nerve-corpuscles. The nuclear masses are traversed throughout by

the fine non-fasciculated nerve fibrils which originate in the granule layers of the bulb. A small medullated band for this olfactory area is also derived from the inner margin of the superficial olfactory fasciculus. An important connexion is established with the motor columns of the cord by fibres passing through this region. This double connexion of the olfactory organ with the cord and cerebrum is the more frequent occurrence in Mammalia. In this olfactory area is an extensive system of arciform medulla, which runs parallel with the cortex at the base destined to reach the under aspect of the callosal commissure through the structure of the septum lucidum.

3. *Arciform Medulla.*—The more important fasciculi, after piercing the callosal commissure, run as a longitudinal band upon the upper surface of that commissure, just before the latter spreads outwards to the cortex of the vertex. Its destination is to the formation of the *modified upper limbic type*, internal to the primary parietal sulcus.

At the occipital extremity of the hemisphere, therefore, there are two important regions characterised as follows:—

a. Modified upper limbic cortex containing a deep belt of granule cells; two well-defined intracortical arciform stripes connected with the cornu ammonis, and the terminal expansions of the olfactory arcuate system.

b. Modified lower limbic type presenting the large inflated cell-formation; two similarly connected arcuate stripes; and lastly the terminal expansion (in the rat) of the central olfactory fasciculus after its decussation in the anterior commissure.

4. *Superficial Olfactory Fasciculus.*—Otherwise termed the outer olfactory root, becomes rapidly attenuated by the termination of its fibres all along its course in the cortex of the anterior and inferior limbic arcs. It has also been stated above that a large fasciculus from its inner margin is distributed to the deep olfactory medulla.

5. *Tænia Semicircularis.*—This arciform band, arising in the cortex of the gyrus hippocampi, and closely following the curved inner surface of the caudate nucleus, is stated by many authorities to terminate in the descending pillar of the fornix. This fact I have been unable to confirm as regards the rabbit and rat, but there are certainly two clearly defined fasciculi which descend from the tænia semicircularis, one to arch round into the anterior commissure, probably decussating here; the other or deeper set of fibres enters the olfactory area. Hence this arcuate band brings the cortex of the gyrus fornicatus into relationship with the olfactory area of its own side and into crossed relationship with the olfactory bulbs, unless the fibres of the tænia entering the anterior commissure are purely commissural in their character.

The Corpus Striatum and its Cortical Connexions.—The following conclusions have been arrived at after a careful study of microscopic sections, and teasing and dissection of the brain. The true striate ganglion is mapped off from the olfactory area and deep medulla by the peculiar formation which I have termed from its configuration the olfactory lyre. In front of the thalamus opticus the coronal connexions betwixt the striate ganglion, capsule, and cerebral cortex arise, *par excellence*, from that marginal aspect of the hemisphere at the vertex, which has been stated to be characterised by an extremely rich ganglionic formation—a region entering largely into the composition of Ferrier's motor realm. As the motor ganglia, however, retire outwards before the intervening thalami, their coronal connexions arise chiefly from the upper and outer aspect of the hemisphere, and still further back from the occipital cortex at their own level. Lastly, the median cortex of the upper limbic arc has throughout its course no connexion whatever with the striate ganglion or internal capsule.

VII. "On the Production of Transient Electric Currents in Iron and Steel Conductors by Twisting them when Magnetised or by Magnetising them when Twisted." By J. A. Ewing, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. Communicated by Professor H. C. Fleeming Jenkin, F.R.S., Professor of Civil Engineering in the University of Edinburgh. Received September 7, 1881.

(Abstract.)

An iron or steel wire subjected to longitudinal magnetisation by a surrounding solenoid gave when twisted a current along itself, which was observed by means of a ballistic mirror galvanometer in circuit with the wire. When the twist was that of a common screw the transient current flowed along the wire from the nominal N. to the nominal S. end. An opposite twist gave an oppositely directed current.

Reversal of the longitudinal magnetisation of the wire, when it was held twisted, gave a strong transient current, but mere interruption or reapplication of the magnetising current gave effects so relatively feeble as not to admit of measurement by the same appliances. When there was no torsion on the wire, reversal of the magnetising force gave no current. The first application of the magnetising force after the wire was twisted gave a current.

A permanently magnetised wire gave when twisted a transient current of the same sign as that described above (from N. to S. if the twist was that of a common screw).

The transient currents produced by twisting a magnetised wire had been noticed by Matteucci as early as 1858 (Wiedemann's "Galvanismus," ii, § 484), but the signs of the effects as observed by him were opposite to those observed by the author, and he did not observe any current when a twisted wire was magnetised. These discrepancies, as well as the evident connexion between the effects under consideration and the remarkable experiments recently described by Professor Hughes ("Proc. Roy. Soc.," vol. 31, p. 525), led the author to examine the subject at length. The results are described fully in the paper.

The statement of the numerical effects, which are at first sight very involved, is much facilitated by the conception that the combined effect of torsion and longitudinal magnetisation is to produce a state, provisionally called "polarisation," in the wire, which persists almost unchanged when the magnetising force is removed. This polarisation is measured by the transient currents which accompany its production. The normal polarisation for a given angle of twist and a given magnetising force is measured by half the ballistic deflection due to the transient current which appeared in the wire when the magnetising force was reversed at that angle of twist. In this way, curves connecting normal polarisation with angle of twist (within the elastic limit) are given for iron and steel. When the wire, after being normally polarised at $+\theta^\circ$, is twisted over to $-\theta^\circ$, the polarisation does not change to the full normal value for $-\theta^\circ$, but to something less, and this difference becomes still more apparent after several twistings from one side to the other. By dividing the full twist across into several steps, cyclical curves have been obtained, showing the relation of polarisation to torsion when the same magnetising force is kept up without interruption or reversal. These curves exhibit, in a striking manner, a persistence of previous state, such as might be caused by molecular friction. The curves for the back and forth twists are irreversible, and include a wide area between them. The change of polarisation lags behind the change of torsion. To this action, which is like that formerly described by the author as a characteristic of the curves connecting thermoelectric quality with longitudinal pull, in a paper on the "Effects of Stress on the Thermoelectric Quality of Metals," Part I, the author now gives the name *Hysterēsis* (ὑστέρησις, from ὑστερέω, to be behind). The modifying influence of "hysteresis" in the whole action is minutely described, and it is shown that the effects of hysteresis may be wiped out by subjecting the wire to mechanical vibration, and still more effectually by changing its magnetisation, which may be done either by breaking and re-making the magnetising current in the solenoid, or by reversing it.

A curve is given showing the relative effects of different values of the magnetising force up to 24 c.g.s. units, from which it appears that a maximum transient current is produced by reversal of the magnetising force when that force is about 15 c.g.s. units. It is probable that by increasing the magnetising force sufficiently the signs of the effects would be reversed.

When torsion is carried beyond the elastic limit the effects become somewhat diminished, and when a permanent twist has been given, and the wire allowed to come back to its new zero of stress, reversals of the magnetising force then give feeble transient currents whose signs are opposite to those of the currents given when the wire is still under torsion.

In steel the general effect is less than in iron, but steel exhibits hysteresis more strongly. With copper, silver, brass, german-silver, and platinum, no effects whatever could be observed. In all probability the effects are peculiar to the strongly magnetic metals.

Having described the experimental results, the author proceeds to point out their relation to the discoveries of Thomson, Villari, Wiedemann, and Hughes, and attempts to explain the production of transient currents by the setting up of a state of circular magnetisation in the wire. Sir W. Thomson's discovery that aelotropic stress developes an aelotropic difference of magnetic susceptibility in iron may be used to account for circular magnetisation by the combined effects of longitudinal magnetisation and torsion. In order that the effects should have the signs which they actually had, this explanation would require that the magnetising force must have been, in all cases, below the Villari critical value at which the effects of push and pull on magnetisation are reversed. It is shown that this may possibly have been the case, and that the same assumption would explain away some of the contradictions between the author's results and the earlier ones of Matteucci.

The paper concludes with some general considerations regarding the phenomenon to which the name "hysteresis" has been applied.

VIII. "The Prehensores of Male Butterflies of the Genera *Ornithoptera* and *Papilio*." By PHILIP HENRY GOSSE, F.R.S. Received October 12, 1881.

(Abstract.)

Anatomists have long ago recognised, in insects, the existence of certain organs, intimately connected with the function of generation, yet perfectly distinct from the organs which perform the proper generative act. They are found only in the male sex; and are considered to have, as their sole use, the office of seizing and holding the female, during the act of coition.

In the detailed examination and comparison of these auxiliary

organs, in the *Lepidoptera*, little seems to have been yet done, except the memoir of Dr. F. Buchanan White, "On the Male Genital Armature in the European Rhopalocera," published in the "Trans. of the Linn. Soc." for December 21, 1876. His investigations prove that the variety which marks these organs—in form, position, and curious armature—is almost endless; and they have opened a quite new field of study in Comparative Entomology, eminently worthy of being further cultivated.

The researches of Dr. White were limited to European forms. The fine butterflies of the vast genus *Papilio*, being trans-European almost exclusively, are scarcely touched by him; and, for obvious reasons, these have been little submitted to destructive dissection and exhaustive examination.

The prehensile auxiliaries to generation, in the restricted genus *Papilio* (including *Ornithoptera*), I have been for some time examining; and I find the variety and singularity of the contrivances displayed therein certainly *not less* conspicuous than Dr. White's researches would lead us to expect. The results are emobdied in the present memoir, which comprises detailed descriptions of the male prehensile apparatus in sixty-nine species (viz., *Ornithoptera*, 11; *Papilio*, 58); illustrated by 196 drawings (viz., *Orn.* 29; *Pap.* 167) of the parts, magnified.

The organs which constitute the special subjects of examination are five in number, viz.:—

1. The Valve.
2. The Harpe.
3. The Uncus.
4. The Scaphium.
5. The Penis.

1. *The Valve.*—Every entomologist knows that the male sex of a swallowtail butterfly is distinguished by its abdomen terminating in two broad ovate plates, called the anal valves, articulated to the eighth segment; convex outwardly, concave inwardly; whose edges are in mutual contact during rest, inclosing and concealing an ample cavity.

2. *The Harpé.*—If we remove one of the valves, and examine its concave inner side, we find a peculiar appendage, to which I give the name of Harpe (ἅρπη), lodged within the hollow. It takes an infinite variety of forms, being never (so far as I have observed) the same in two species, however nearly they may be affined. It is, in general, a weapon of hard, horny chitine, usually glittering like glass, articulated in part to the base of the inclosing valve, in part to a projecting knob of chitine within the bottom of the eighth segment. It lies in the valve-cavity, to whose lining membrane it is affixed, to a certain extent;

but its distal moiety is free, projected, and antagonised to that of its opposite fellow.

It is in this free portion that the wondrous variety mainly resides; and the equally wondrous perfection of elaborate armature. It simulates, with curious precision, our knives, swords, sickles, axes, saws, and pikes, straight, angled, or curved; now furnished with one or more acute needle-points, now bearing a keen cutting edge, now cut into spinous teeth, now with each tooth notched into secondary minuter teeth; sometimes it is a broad disk, beset with conical prickles, sometimes a long elastic wire; besides many other forms, simple and compound, for which our human implements afford no comparisons.

That the proper specific office of these elaborate contrivances is the prehension of the female during the copulative act, is not left to be conjectured; for they often carry *documentary* evidence that they have been so employed. Very often, when a valve is exposed, the armature is quite invisible, because the cavity is wholly filled with a brown deposit, caked into a solid mass. This, when put on a slip of glass with a drop of water, under the microscope, is presently resolved into a multitude of body clothing-scales, clogged together with dried remains of what had been the anal fluid (*meconium*) of some female butterfly; that brown fluid which is always discharged soon after evolution from pupa. In such a case, conjunction had been effected with a female *just evolved;* the serrate harpe-claws of the male had scraped off a crowd of scales in the efforts to obtain prehension; while the excitement had caused the female to discharge the meconium at the same moment. And here remained the stereotyped record!

3. *The Uncus.*—The dorsal arch of the eighth abdominal segment terminates, generally, in a slender spine of polished, elastic chitine, which, continuing the medial line, projects backward, and arches down, so as to form a (more or less) semicircular hook. To this I appropriate the term *Uncus.* Its office seems to be to secure a *vertical* grasp of the female organs, which are simultaneously grasped, *laterally*, by the right and left harpes. But the shape, direction, curvature, texture, and adjuncts of this organ vary exceedingly; and sometimes it is altogether lacking.

4. *The Scaphium.*—This is an organ to which I have not been able to find distinct allusion in any author. In the other families of *Rhopalocera* it seems altogether wanting.* Yet, in the *Papilionidæ* proper, it is generally large, conspicuous, and complicate. If we remove the valve of *Ornithoptera Haliphron*, or *Papilio Pammon*, the

* Save in the *Pieridæ.* In the South American *Gonepteryges*, *Clorinde*, and *Leachiana*, it is well formed, but minute: in the Oriental *Hebomoia Glaucippe*, moderately large, but peculiar: it becomes evanescent in *Terias.*

eye is arrested at once by a great mass of firm flesh, white like polished ivory, projecting from the abdomen immediately under the *uncus:* this is the organ which, from a prevailing resemblance in shape to a boat, I call *Scaphium*. Of its function I remain ignorant: yet, since, in some species, it is most elaborately and formidably armed—as in *P. Macedon*, *Mayo*, *Thoas*, and, most of all, *Merope*—with teeth, and spines, and saws, I conclude that it must serve for prehension; though the question, "How?" is very difficult to answer; and though it very probably has *other* offices.

There is a manifest organic connexion between the scaphium and the uncus; like that organ it is occasionally wanting; but sometimes the uncus is present when the scaphium is absent, and sometimes the case is reversed.

5. *The Penis.*—This organ should strictly form no part of my subject, which is not the function of generation, nor the organs that perform it, but certain prehensile apparatus that are ancillary to the performance. The penis is a principal, not an auxiliary; yet, as it is essentially the centre, around which the whole armature waits and serves, and as it forms so conspicuous an object in the grouping of the whole, I could scarcely avoid representing it in the drawings, or giving some account, at least of its varying form and position.

Some curious phenomena, moreover, have occurred in the organ, which seemed to me worthy of being detailed and figured. Particularly the occasional development of a white pulpy tissue filling the chitinous tube, and evidently very distinct from it; and, in some instances, the extrusion of this tissue from the orifice, as a columnar or globular mass, which bears curious evidences of its having been forcibly extruded, in a condition at least semi-solid, and by successive spasms.

In some species, as the Oriental *P. Cöon* and its allies, this organ is excessively attenuated, and as excessively lengthened, so as protrude far beyond the limits of the valves, when these are normally closed; and so as to be quite apparent in the cabinet, like a projecting fine wire, with which one may readily take up and handle the specimen, as if it were an inserted pin.

All of these organs may be studied together, and with unusual facility, in *Ornithoptera Rhadamanthus* and in *Papilio Merope;* Plates I and IV of this memoir.

As the harpe appears to be the leading organ in the prehensile apparatus, the most fully elaborated and the most varied, I have employed its variations of form to cast into groups the species treated. This grouping is not proposed, in any sense, as a natural arrangement; but as a help to reference, and as a means of comparison of the varying conditions of the organ.

One of the results, not the least curious, of this grouping, is the wide separation of species apparently very closely allied. Thus *Ornith. Haliphron* and *O. Amphrysus*, Cram., are radically different in the forms of their respective harpes. *P. Demoleus* and *P. Erithonius*, so very consimilar in the shape, colours, and patterns of their wings, are quite unlike in their harpes. *P. Bromius*, *P. Nireus*, and *P. Phorcas* have the harpe of a quite different *type* and *plan* in each! On the other hand, *P. Machaon* and *P. Arcturus* are consimilar in armature; while *P. Agavus* and *P. Hector* are as wide as the poles apart!

It must not be forgotten that the armature of not more than a sixth part of the 400 and upward described *Papiliones* is here represented. A further prosecution of the inquiry will certainly bridge-over many gaps, and supply other characteristic forms.

IX. "On the Propagation of Inhibitory Excitation in the Medulla Oblongata." By Dr. H. KRONECKER and Mr. S. MELTZER, Candidate in Medicine, Berlin. Communicated by Dr. BURDON SANDERSON, F.R.S. Received October 18, 1881.

In the Royal Academy of Science of Berlin, on the 24th January, 1881, a communication from us, "On the Mechanism of Deglutition and its Inhibitory Nerves," was read by Professor E. du Bois-Reymond. The experiments described were performed by means of a slightly inflated caoutchouc ball, fastened to the blind end of an œsophageal tube, the other end of which was connected with a Marey's tambour, whose lever recorded the movements on the blackened surface of a rotating cylinder. The ball was introduced, for varying distances, into the œsophagus, and the movements recorded resulting from the swallowing of small quantities of fluid.

It has previously been shown (Falk and Kronecker) that, in man and in the dog, the act of deglutition proper is accomplished by the quick contraction of the *striated* muscles, and that the draught reaches the stomach even before the œsophageal contraction can make itself effective. In one of our former investigations, Mr. Meltzer, by experiments performed on himself, showed that a mouthful of water reaches the stomach in less than 0·1 second after being swallowed, but that the peristaltic action does not appear in the uppermost part of the œsophagus sooner than about 1·0 second after the beginning of the act of deglutition, and does not reach the stomach till 5—6 seconds later. In the communication mentioned above, the results of still more recent investigations were given. It was found that in the uppermost portion of the œsophagus of man, extending about 6—8 centims. from the lower border of the pharynx, the contraction lasted 2—3 seconds, and in the deep portion, about 12 centims. in extent from the cardia, 8—9 seconds, and that the transition from the region of shorter to that of longer contraction occurred in a short portion, about 4 centims. long, about the level of the manubrium sterni. It is a physiological characteristic of this region that in it the transition from the striated to the smooth muscles occurs (E. Weber).

In determining the period of latent stimulation for the purpose of measuring the speed of propagation of the peristaltic waves, it was found that the period increased not gradually but by bounds. Thus, in the upper portion of the œsophagus, 8 centims. long, measuring from the beginning, the period of latent stimulation amounts to from 1 to 1·5 seconds; in the following portion, 8 centims. long, from 3 to 3·5 seconds, and in the undermost portion, from about 5·5 to 7 seconds. From these researches it appeared highly probable that the reflex ganglia of deglutition are arranged in three groups connected with one another. But the experiments seemed also to show that there must be a fourth group, placed near to the other three, through which the first reflex of the act of swallowing occurs. This uppermost group is more closely related with the lower three than these with one another, since we have found that the three regions of the œsophagus can contract, from above downwards in orderly sequence, without a first act of swallowing having occurred. This happens in consequence of "eructation," which effects a separate irritation on the three lower ganglion groups of deglutition.

When one makes a series of acts of swallowing quickly one after the other, as in drinking a glass of water, the registering ball shows that *one* œsophageal contraction follows, and that only after the last of the series; and its occurrence is timed, in reference to the last draught, as if it had been produced by a single act of swallowing. It therefore appeared :—

I. *That the beginning of every act of swallowing not only* excites *the œsophageal contraction related to it, but, at the same time,* restrains *the contraction, excited shortly before, but which has not yet occurred. This inhibition is capable of preventing the contraction even immediately prior to its appearance.*

It is therefore to be concluded that the restraining excitation, traversing the direct motor tracts, outruns the motor excitation, advancing through the ganglion groups.

If a second act of swallowing occurs when the œsophageal contraction, following the first, has already begun, this contraction can no longer be restrained. In such a case, however, the contraction corresponding to the second act begins as late as if this second act had not been performed till after the completion of the first contraction. In other words :—

II. *The second motor irritation is effective only when the contraction following the first has passed.*

The anatomical tracts, along which this inhibition is conducted, we have found to be the ramifications of the ninth pair of cranial nerves, the Nn. Glossopharyngei.

III. *If the trunk of the glossopharyngeus is irritated, no movement of deglutition results, in spite of the strongest excitation to deglutition, produced by filling of the pharynx with fluid, or by stimulation of the Nn. laryngei superiores. Both the first reflex act of swallowing and the œsophageal contraction are for the time in abeyance.*

IV. *If the pharyngeal branches only are irritated, then the inhibitory phenomenon appears in the cervical or in the thoracic portion of the œsophagus.*

The pharyngeal branches of the N. Glossopharyngeus are not unfrequently distributed in company with the pharyngeal branches of the N. vagus, so that as a complete anatomical separation of the ninth and tenth nerve pairs cannot be effected; neither can a physiological.

V. *If the N. glossopharyngeus be cut through, the œsophagus falls into tonic spasm, which may last longer than one day.*

It was in continuation of these researches, that the following new and noteworthy observations were made.

The excitations, which reach their centre in the medulla oblongata through the N. glossopharyngeus, exert an inhibitory influence, not only on the origins of those vagus fibres which supply the œsophagus, but also on the ends of the vagus fibres which *excite* the movements of respiration and *restrain* those of the heart. Lastly, the inhibitory influences extend also to the centre in the medulla regulating the blood-vessels. This can be shown in normal living man. One can, by swallowing, easily observe the following:—

I. *During each act of swallowing the pulse frequency increases.*

II. *During a series of acts the need of respiration decreases.*

III. *During each act of swallowing the blood pressure falls in the aortic system.*

This remarkable proposition, therefore follows: *that excitations, which are conveyed to the centre along the tracts of the inhibitory nerves, extend in the character of inhibitions to neighbouring centres.*

Continued researches on the operation of these newly discovered inhibitory nerves promise specially interesting disclosures, for this reason, that they can be set into activity through normal excitations, voluntarily produced, while the observations on the working of the N. vagus, the chief representative of the inhibitory nerves, can be performed only by means of artificial irritation, whose correspondence with natural irritation has by no means been admitted by all.

X. "On the Refraction of Plane Polarised Light at the Surface of a Uniaxal Crystal." By R. T. GLAZEBROOK, M.A., Fellow and Assistant Lecturer of Trinity College, Demonstrator in the Cavendish Laboratory, Cambridge. Communicated by Lord RAYLEIGH, M.A., F.R.S. Received October 27, 1881.

(Abstract.)

The paper, of which the following is an abstract, contains an experimental investigation of the relation between the plane of polarisation of light falling on the surface of a crystal of Iceland spar and the angles of incidence and refraction in the cases in which only one refracted wave traverses the crystal. A prism was cut from a piece of spar, one face of the prism coinciding almost exactly with a rhombic face, and plane polarised light allowed to fall on it at a known angle of incidence. The deviation of light of a definite wave-length in both the ordinary and extraordinary spectrum is observed, and from that and the angle of incidence ϕ we can calculate ϕ' and ϕ'', the two angles of refraction. The polariser being then turned until the ray in question disappears from the extraordinary spectrum its position is noted. A known small rotation is then given to the plane of polarisation of the incident light either by turning the polariser through a known angle, or introducing into the path of the light a cell containing a solution of sugar. This causes the reappearance of the ray in question in the extraordinary spectrum, and the spar prism is then moved, thus varying the angle of incidence until it again disappears. The angle of incidence and the deviation of the same ray in the ordinary spectrum being measured, we get a second pair of values of ϕ and ϕ' under the condition that the ordinary ray only traverses the crystal. Now if β be the angle which the optic axis makes with the edge of the prism, λ the angle between the face of incidence and a plane through the optic axis and the edge of the prism, and θ the angle between the direction of vibration of the incident light and this same edge, it follows, either from the electro-magnetic theory of light (Lorentz, "Schlömilch Zeitschrift," vol. 22; Fitzgerald, "Phil. Trans.," vol. 171, 1880), or the theories of Neumann ("Abhand. Akad. Berlin," 1835), MacCullagh ("Trans. Roy. Irish Acad." 1839), and Kirchhoff ("Abhand. Akad. Berlin," 1876), that if the ordinary ray only traverses the crystal—

$$\cot\theta=\tan\beta\cos(\lambda+\phi')\sec(\phi-\phi').$$

We are thus able to obtain a series of theoretical values of θ. The difference between two consecutive values should, if the theory be true, give us the angle through which the plane of polarisation has

been turned. There is some difficulty in determining with certainty the angle between the edge of the prism, from which θ is measured, and the principal plane of the polarising prism in any given position. We, therefore, cannot compare a series of observed and calculated values of θ with accuracy; we can, however, compare the differences between consecutive values of θ given by theory with those differences as produced by the known rotation of the polarising Nicol, or that due to the sugar cell.

Similar observations were made for the case in which only the extraordinary ray traverses the crystal; in this case, if a and b be the principal refractive indices, we have, according to the same theories,—

$$\tan\theta=\tan\beta\cos(\lambda+\phi'')\cos(\phi-\phi'')+\frac{a^2-b^2}{2a^2}\frac{\sin 2\beta\sin(\lambda+\phi'')\sin^2\phi}{\sin(\phi+\phi'')\cos^2\theta''},$$

where θ'' is given by

$$\tan\theta''=\tan\beta\cos(\lambda+\phi'').$$

Two series of observations are recorded in the paper, the one made in November, 1880, the other with new and improved apparatus in August, 1881.

The two series lead to practically identical results. Taking first the case in which the ordinary wave only is transmitted; for high angles of incidence the rate of change in the values of θ as given by theory is considerably greater than that given by experiment. When ϕ lies between 40° and 55° (about), the two agree closely, and as the angle of incidence decreases still further, there is a tendency for the experimental value of the difference to become the greater.

The differences between theory and experiment amount to 6 per cent. of the quantity measured when the ordinary wave is transmitted, and to 15 per cent. when the extraordinary wave only passes through the prism.

When only the extraordinary wave is transmitted the reverse is the case, the theoretical value is for large values of ϕ too small; for angles between 40° and 55° the two agree fairly, and for smaller angles the experimental value becomes too small. Other series of experiments lead to the same conclusions. For details as to the arrangements of the apparatus, the method of determining exactly when one ray is quenched, the probable accuracy of the results, and the effects of small errors in the constants of the formulæ or the adjustment of the apparatus, reference must be made to the paper.

The experiments were conducted by Lord Rayleigh's kind permission in one of the rooms of the Cavendish Laboratory, at Cambridge.

XI. "On Allotropic or Active Nitrogen, and on the Complete Synthesis of Ammonia." By GEORGE STILLINGFLEET JOHNSON, King's College. Communicated by Professor G. JOHNSON, F.R.S. Received October 8, 1881.

[Publication deferred.]

XII. "Researches on Chemical Equivalence. Part IV. Manganous and Nickelous Sulphates." By EDMUND J. MILLS, D.Sc., F.R.S., and J. H. BICKET. Received October 25, 1881.

[Publication deferred.]

XIII. "Researches on Chemical Equivalence. Part V." By EDMUND J. MILLS, D.Sc., F.R.S., and BERTRAM HUNT. Received October 27, 1881.

[Publication deferred.]

November 24, 1881.

THE PRESIDENT in the Chair.

In pursuance of the Statutes, notice was given from the Chair of the ensuing Anniversary Meeting, and the list of Officers and Council nominated for election was read, as follows:—

President.—William Spottiswoode, M.A., D.C.L., LL.D.

Treasurer.—John Evans, D.C.L., LL.D.

Secretaries.— { Professor George Gabriel Stokes, M.A., D.C.L., LL.D.
Michael Foster, M.A., M.D., LL.D.

Foreign Secretary.—Professor Alexander William Williamson, Ph.D., LL.D.

Other Members of the Council.—Francis Maitland Balfour, M.A., LL.D.; I. Lowthian Bell, F.C.S.; Sir Risdon Bennett, M.D.; Professor Thomas George Bonney, M.A.; Professor Heinrich Debus, Ph.D.; Alexander John Ellis, B.A.; Sir John Hawkshaw, M.I.C.E.; Thomas Archer Hirst, Ph.D.; William Huggins, D.C.L., LL.D.; Professor Thomas Henry Huxley, LL.D.; Professor Joseph Lister, M.D.; Professor Daniel Oliver, F.L.S.; Professor Henry Enfield Roscoe, B.A., LL.D.; Warington W. Smyth, M.A.; Henry Tibbats Stainton, F.G.S.; Edward James Stone, M.A.

The Presents received were laid on the table, and thanks ordered for them.

THE BAKERIAN LECTURE—"Action of Free Molecules on Radiant Heat, and its Conversion thereby into Sound," was delivered by J. TYNDALL, F.R.S.

The following is an abstract:—

The lecture opens with a brief reference to the researches of Leslie, Rumford, and Melloni. The labours of Tyndall and Magnus, as far as they bear upon the present subject, are then succinctly sketched, their points of difference being signalised and briefly discussed. This preliminary sketch is wound up by a reference to a recently published paper by Lecher and Pernter, who, while supporting the lecturer in the matter of gases, dissent from him in the matter of vapours. These investigators are especially emphatic in affirming the neutrality of aqueous vapour to radiant heat. Following Magnus, they refer Tyndall's results to what Magnus calls "vapour-hesion," that is to say, to the condensation of the vapours on the surfaces of the plates of rock-salt used to close the experimental tube, and on the interior surface of the tube itself.

In November, 1880, the lecturer's investigations in this field were resumed. Former experiments were repeated and verified with divers sources of heat, and with various experimental tubes—some polished within, and others coated inside with lampblack. The results obtained with the one class of tubes are substantially the same as those obtained with the other.

But even a coating of lampblack may be supposed to reflect a certain amount of heat, hence the desirability of an arrangement whereby internal reflection should be entirely abolished. This was accomplished in the following manner:—A spiral of platinum wire, rendered incandescent by a voltaic current of measured strength, was chosen as source of heat. An experimental tube 38 inches long and 6 inches in diameter had two circular apertures at its ends, closed by transparent plates of rock-salt, 3 inches in diameter. The tube was furnished with three cocks—one connected with a large Bianchi's air-pump; another with a purifying apparatus; while through the third vapours and gases could be admitted. Prior to entering the tube, the calorific rays were sent through a very perfect rock-salt lens, by means of which an image of the spiral was formed on the most distant plate of rock-salt. To obtain the image with clearness, the spiral was first rendered highly luminous, and afterwards reduced, by the introduction of resistance, to the required temperature. In this way a calorific beam was sent along the axis of the experimental tube without at all impinging upon its interior surface. No reflection came into play; no absorption by hypothetical liquid films, coating the internal surface, could occur; and yet experiments made with this arrangement entirely confirmed the preceding ones, wherein by far the greater quantity of heat which reached the pile had undergone reflection.

When the source of heat was changed to a carefully worked cylinder of lime, a portion of which was rendered incandescent by an ignited stream of coal-gas and oxygen, the results were confirmatory of those obtained with the spiral. The order of absorption in bot cases was the same, the only difference being that the fractional part of the total radiation absorbed in the case of the lime-light was less than that absorbed in the case of the spiral.

To condense the radiation from the lime-light, concave mirrors were sometimes employed, and sometimes rock-salt lenses. The results in both cases were identical.

An experimental tube of the dimensions here given was employed by the lecturer to check his results more than ten years ago. Its interior surface was rough and tarnished, and when warmed dynamically by the entrance of a gas its power as a radiator enabled it to disturb, to some slight extent, the purity of the results. To obviate this, the experimental tube recently employed was provided with an internal silver surface, deposited electrolytically and highly polished. By this arrangement the radiation of the tube itself, as well as its absorption, was rendered quite insensible.

The rock-salt plates used to close the experimental tube, and on which liquid films are alleged to be deposited, remain to be examined. In this case also an *experimentum crucis* is possible. If the observed absorptions be due to such liquid films, then the separation of the salts more widely from each other, the space between them being copiously supplied with vapour, ought to produce no effect; but if the absorption, as alleged by the lecturer, be the act of the vapour molecules, then the deepening of the absorbing stratum ought to produce an augmented effect. For many gases and some vapours this problem was solved as far back as 1863. By means of an apparatus then described, polished plates of rock-salt could be brought into contact with each other, and then gradually separated, until the gaseous stratum between them was some inches in depth. With sulphuric ether vapour the distance between the plates being $\frac{1}{20}$ of an inch, an absorption of 2 per cent. was observed. With a thinner stratum, or a weaker vapour, even this small absorption vanished; while in passing from

$\frac{1}{20}$ of an inch to 2 inches the absorption rose from 2 per cent. to 35 per cent. of the total radiation. Such experiments, recently verified, entirely dispose of the hypothesis that liquid films were the cause of the observed absorption.

The "vapour-hesion" hypothesis involves the assumption that liquids exert on radiant heat an absorbent power which is denied to their vapours. It assumes, in other words, that the seat of absorption is the molecule considered as a whole, and not the constituent atoms of the molecule. For were the absorption intra-molecular, the passage from the liquid to the vaporous condition, which leaves the molecules intact, could not abolish the absorption. So far back as 1864 the lecturer had proved that when vapours, in quantities proportional to the densities of their liquids, were examined in the experimental tube, the order of their absorptions was precisely that of the liquids from which they were derived. This result has been recently tested and verified in the most ample manner by means of the apparatus in which internal reflection never comes into play. It furnishes, therefore, the strongest presumptive evidence that the seat of absorption in liquids and in vapours is the same.

As a problem of molecular physics it was, however, in the highest degree desirable to compare together *equal* quantities, instead of proportional quantities, of liquids and vapours. Highly volatile liquids alone lend themselves to this experiment, for only from such liquids can vapours be obtained sufficient, when caused to assume the liquid form, to produce layers of practicable thickness. Two cases, however, have been very fully worked out, the substances employed being the hydride of amyl and sulphuric ether. Careful and exact experiments, many times repeated, lead to the result that when the number of molecules traversed by the calorific rays in the vapour is the same as that traversed in the liquid, the absorptions are identical. In the silvered experimental tube, which, as stated, is 38 inches long, hydride of amyl vapour, at a mercury pressure of 6·6 inches, is equivalent to a liquid layer 1 millim. in thickness, while a vapour column of sulphuric ether, of the same length, and 7·2 inches pressure, would also produce a liquid layer 1 millim. thick. The experiment has been made with the utmost care, both with the lime-light and the incandescent platinum, with the result that it is impossible to say that there is any difference between the vapour absorption and the liquid absorption. In the face of such facts the "vapour-hesion" hypothesis, as an explanation of the results published by the lecturer, cannot be sustained.

On the 29th of November, 1880, he had the pleasure of witnessing, in the laboratory of the Royal Institution, the experiments of Mr. Graham Bell, wherein a concentrated luminous beam, rendered intermittent by a rotating perforated disk, was caused to impinge upon various solid substances, and to produce musical sounds. Mr. Bell's previous experiments upon selenium naturally led him to conclude that the effect was produced by the luminous rays of the spectrum. The contemplation of these experiments produced in the lecturer the conviction that the results were due to the intermittent absorption of radiant heat. He was experimenting on vapours at this time. Substituting in idea gaseous for solid matter, he clearly pictured the sudden expansion of an absorbent gas or vapour at every stroke of the calorific beam, and its contraction when the beam was intercepted. Pulses far stronger than those obtainable from solid matter would probably be thus produced, which, when rapid enough, would generate musical sounds. The intensity of the sound would, of course, be determined by the absorptive power of the gas or vapour.

This idea was tested on the spot. Placing sulphuric ether in a test-tube, and connecting the tube with the ear, the intermittent beam was caused to fall upon the vapour above the liquid. A feeble musical sound was distinctly heard. Formic ether was tried in the same way, and with the same result. Bisulphide of carbon was then tried, but the vapour of this liquid proved incompetent to generate a musical sound. These results, which were in perfect accordance with those previously enunciated by the lecturer, were first made public during a discussion at the Society of Telegraph Engineers on the 8th of December, 1880.*

It was obvious, however, that the arrangement of Mr. Bell—a truly beautiful one—was not suited to bring out the maximum effect. He had employed a series of lenses to concentrate his beam, and these, however pure, would, in the case of transparent gases, absorb a large portion of the rays most influential in producing the sound. The lecturer, therefore, resorted to lenses of rock-salt and to concave mirrors silvered in front. He employed various sources of heat, including that of the electric lamp. The lime-light he found very convenient. With the lime-light and concave mirror, sounds of surprising intensity were produced by all the highly absorbent gases and vapours. Among gases chloride of methyl was loudest. Conveyed directly to the ear by a tube of india-rubber, the sound of this gas seemed as loud as the peal of an organ. Abandoning the ear-tube, and choosing a suitable recipient for the gas, the sounds were heard at a distance of 20 feet from their origin. As regards intensity, the order of the sounds, in gases, corresponds exactly with the order of their absorptions of radiant heat.

Among vapours sulphuric ether stands highest, this result being in part due to the great volatility of the liquid. But the intensity of the sound is by no means wholly dependent on volatility. The specific

* "Journal of Telegraph Engineers," vol. 9, p. 382.

action of the molecules on radiant heat is as clearly shown in these experiments as in those previously conducted with the experimental tube and thermopile. Upwards of eighty vapours have been tested in regard to their sound-producing power.

With regard to aqueous vapour, whose action upon radiant heat even the latest publications on this subject describe as *nil*, it was especially interesting to be able to question the vapour itself as to its absorbent power, and to receive from it an answer which did not admit of doubt. A number of bulbs about an inch in diameter were placed under the receiver of an air-pump, with a vessel containing sulphuric acid beside them. When thoroughly dry they were exposed to an intermittent beam. The well-dried air within the bulbs proved silent, while the slightest admixture of humid air sufficed to endow it with sounding power. Placing a little water in a thin glass bulb, and heating it nearly to its boiling point, the sounds produced by the developed vapour are exceedingly loud. The bulbs employed in these experiments are usually about a cubic inch in volume. They may, however, be reduced to one-fiftieth or even one one-hundredth of a cubic inch. When a minute drop of water is vaporised within such little bulbs, on their exposure to the intermittent beam loud musical sounds are produced.

It is to be borne in mind, that the heat employed in these experiments, coming as it did from a highly luminous source, was absorbed in a far smaller degree than would be the heat from bodies under the temperature of incandescence.

To render the correlation of sound-producing power and adiathermancy complete, all the gases and vapours which had been exposed to the intermittent beam were examined as to the augmentation of their elastic force through the absorption of radiant heat. A glass cylinder, 4 inches long and 3 inches in diameter, had its ends closed with transparent plates of rock-salt. Connected with this cylinder was a narrow U-tube, containing a coloured liquid which stood at the same level in the two arms of the U. The cylinder could be exhausted at pleasure or filled with a gas or vapour. When filled, the sudden removal of a double silvered screen permitted the beam from the lime-light to pass through it, the augmentation of elastic force being immediately declared by the depression of the liquid in one of the arms of the U-tube and its elevation in the other. The difference of level in the two arms gave, in terms of water-pressure, a measure of the heat absorbed. With the stronger vapours it would be easy with this instrument to produce an augmentation of elastic force corresponding to a water-pressure of a thousand millimetres. As might be expected, the intensity of the sounds corresponded with the energy of the absorption, varying from "exceedingly strong," "very strong," "strong," "moderate," "weak," to "inaudible." In this connexion reference was made to the interesting experiments of Professor Röntgen, an independent and successful worker in this field.

In conclusion, the lecture draws attention to the bearing of its results upon the phenomena of meteorology. The views of Magnus regarding the part played by mist or haze, are referred to and attention is directed to various observations by Wells which are in opposition to these views. The observations of Wilson, Six, Leslie, Denham, Hooker, Livingstone, Mitchell, Strachey, and others are referred to and connected with the action of aqueous vapour upon solar and terrestrial radiation. Many years ago the lecturer sought to imitate the action of aqueous vapour on the solar rays by sending a beam from the electric light through a layer of water, and afterwards examining its spectrum. The curve representing the distribution of heat resembled that obtained from the spectrum of the sun, the invisible calorific radiation being reduced by the water from nearly eight times to about twice the visible. Could we get above the screen of atmospheric vapour, a large amount of the ultra-red rays would assuredly be restored to the solar spectrum. This conclusion has been recently established on the grandest scale by Professor Langley, who on the 10th of September wrote to the lecturer from an elevation of 12,000 feet on Mount Whitney, "where the air is perhaps drier than at any other equal altitude ever used for scientific investigation." An extract from Professor Langley's letter will fitly close this summary:—"You may," he says, "be interested in knowing that the result indicates a great difference in the *distribution* of the solar energy here from that to which we are accustomed in regions of ordinary humidity, and that while the evidence of the effect of water vapour on the more refrangible rays is feeble, there is, on the other hand, a systematic effect, due to its absence, which shows, by contrast, its power on the red and ultra-red in a striking light. These experiments also indicate an enormous extension of the ultra-red rays beyond the point to which they have been followed below, and being made on a scale different from that of the laboratory—on one indeed as grand as nature can furnish—and by means wholly independent of those usually applied to the research, must, I think, when published, put an end to any doubt as to the accuracy of the statements so long since made by you, as to the absorbent power of water-vapour over the greater part of the spectrum, and as to its predominant importance in modifying to us the solar energy."

November 30, 1881.

ANNIVERSARY MEETING.

THE PRESIDENT in the Chair.

The Report of the Auditors of the Treasurer's Accounts on the part of the Society was presented, by which it appears that the total receipts during the past year, including a balance of £1,195 5*s*. 1*d*. carried from the preceding year, amount to £8,020 3*s*. 8*d*.; and that the total expenditure in the same period, including purchase of stock, amounts to £5,760 19*s*. 1*d*., leaving a balance at the Bankers' of £2,241 11*s*. 8*d*., and £17 12*s*. 11*d*. in the hands of the Treasurer.

The thanks of the Society were voted to the Treasurer and Auditors.

The Secretary read the following Lists:—

Fellows deceased since the last Anniversary.

On the Home List.

Addison, William, M.D.
Beaconsfield, Benjamin Disraeli, Earl of, K.G.
Bigsby, John Jeremiah, M.D.
Billing, Archibald, M.D.
Caithness, James Sinclair, Earl of.
Colvile, Right Hon. Sir James William, Knt.
Currey, Frederick, M.A.
Davis, Joseph Barnard, M.D.
Egerton, Sir Philip de Malpas Grey, Bart.
Gould, John, V.P.Z.S.
Greswell, Rev. Richard, M.A.
Gunn, Ronald Campbell, F.L.S.
Hatherley, William Page Wood, Lord.
Johnson, The Very Rev. George Henry Sacheverell, M.A.
Jones, Thomas Rymer.
Lloyd, Rev. Humphrey, D.D.
Luke, James, F.R.C.S.
Mallet, Robert, C.E.
Rolleston, George, M.D.
Stanford, John Frederick, M.A.
Stanley, The Very Rev. Arthur Penrhyn, D.D.
Stenhouse, John, LL.D.
Thornton, Henry Sykes, M.A.

On the Foreign List.

Chasles, Michel.

Change of Name and Title.

Lindsay, Lord, *to* Earl of Crawford and Balcarres.

Fellows elected since the last Anniversary.

Ayrton, Prof. William Edward.
Bates, Henry Walter.
Bristowe, John Syer, M.D., F.R.C.P.
Christie, William Henry Mahoney, M.A.
Dickie, Prof. George, A.M., M.D., F.L.S.
Gladstone, Right Hon. William Ewart, D.C.L.
Grant-Duff, Right Hon. Mountstuart Elphinstone.
Kempe, Alfred Bray, B.A.
Macalister, Prof. Alexander, M.D., Sec. R.I.A.
McLeod, Prof. Herbert, F.I.C., F.C.S.
Phillips, John Arthur.
Preece, William Henry, C.E.
Samuelson, Bernhard, M.I.C.E.
Stoney, Bindon Blood, M.A., M.I.C.E.
Traquair, Ramsay H., M.D.
Watson, Rev. Henry William, M.A.
Wright, Charles R. Alder, D.Sc.

On the Foreign List.

Daubrée, Gabriel Auguste.
Marignac, Jean Charles Galissard de.
Nägeli, Carl.
Weierstrass, Carl.

The President then addressed the Society as follows:—

On the occasions of our anniversary our first glance is usually retrospective, in memory of those once among our numbers, but now surviving only in their works. On our home list we have this year lost more than a score of Fellows. On the foreign list we have lost but one; that loss will however be severely, if not so widely, felt.

In Michael Chasles mathematicians recognise a geometer of unusual powers, who, having devoted a long life to his favourite study, has left an extensive and characteristic train of researches behind him. But a larger circle of friends recognised in him a great and good man, beloved by all who knew him, and respected beyond the range of his personal acquaintance. As a pure geometer he belonged to a class of mathematicians for which the Academy of Sciences of Paris has long been justly celebrated; but whose numbers appear liable to a perceptible fluctuation, perhaps partly owing to the brilliant opportunities and the varied fascinations which modern algebra offers to the student. Eminent in a nation which has always been intolerant of obscurity in Science, he showed in a remarkable degree how much might be elicited through precision of thought and by clearness of exposition from a few well-selected and fertile ideas. Such, for instance, proved to be the consideration of Anharmonic Ratios, the principle of Correspondence, and the method of Characteristics. Whether in the latter he had struck a vein so completely out of the range of the analyst, as he himself supposed, may perhaps be still claimed as an open question;

but certain it is that he showed the fertility of the method by continuing to deduce from it an apparently inexhaustible flow of theorems, even after the more serious part of his mathematical work had been done. And there is little doubt that long after the time when many subsequent works have fulfilled their purpose, and have fallen into a natural oblivion, his "Aperçu Historique," his "Géometrie Supérieure," and the fragment of his "Traité des Sections Coniques," will be regarded as classics in the library of the mathematician.

Turning to the home list, the remark made in my last address, viz., that our losses had been mainly among our older Fellows, might be repeated with even more emphasis on the present occasion. Of the twenty-two who have died during the intervening period nine had reached the age of three score and ten, eight that of four score, and one, Dr. Billing, had attained his ninety-first year.

In Lord Beaconsfield and Sir James Colvile we have lost two distinguished members, elected under the statute which gave a new definition of the privileged class a few years ago. Lord Hatherley will be recollected as having served on our Council within recent years, and as having often given us very useful advice on subjects requiring the sound judgment of an experienced mind. Although Lord Hatherley would doubtless have been elected, as a member of the Privy Council, under the statute above mentioned, it is perhaps worth remark that he was elected under statute previously existing, and that his fellowship dated from the year 1833.

The late Dean of Westminster furnishes another instance of the wise exercise of a power which the Royal Society has always reserved to itself, notwithstanding the changes made in 1847, of electing from time to time men of eminent distinction in other avocations of life than those of strict science. Of Dr. Stanley's attainments and merits in those other directions it is not my province to speak; and, indeed, it is the less necessary that I should do so, for they were so many and so varied that in one way or other they were known to all. But he was conspicuous, both among the members of his own profession and among many others who have neither predilection nor training for actual science, for his genuine and honest sympathy with its principles and its objects, and with the labours of those who cultivate it.

In Dr. Lloyd, whose age was coeval with the century, and who was a fellow-worker with Herschel, Whewell, Peacock, and Sir W. R. Hamilton, we seem to have lost one of the links which connected us with a past generation. While himself no mean mathematician, he was distinguished especially in the sciences of optics and of magnetism. In the subject of optics he had the rare opportunity of supplying the experimental verification of Sir W. R. Hamilton's brilliant geometrical conclusions on the configuration of the wave-surface; and it was largely due to his patience, his delicacy of touch, and his almost instinctive sagacity, that the phenomena of conical refraction were first made visible to human eye. In magnetism he assisted in the formation of the great survey of the globe, initiated by Sir E. Sabine, and as director of a magnetic observatory in Dublin he made valuable contributions to the subject. His scientific remains, brought together in one volume, have been a welcome addition to the library both of the mathematician and of the experimentalist. His interest in science and in its promoters was active throughout his long life; and those on whom the honorary degree of LL.D. was conferred at the late meeting of the British Association in Dublin, will always cherish as a pleasant reminiscence the fact of having received it at his hands.

Dr. Bigsby was one of the earlier cultivators of Geology. Some of his first studies were made at a time when the subject was hardly a science; but in attaining the advanced age of eighty-nine he lived to see it what it has since become. He founded a medal at the Geological Society, of which he was for many years a member.

We are again reminded of the progress which has been made in science, and in the cultivation of it during the present generation by the fact that until the last day of last year we could reckon among our Fellows Dr. John Stenhouse, one of the surviving founders of the Chemical Society.

On the subject of our property there is little change to report. Further investments have been made in due course on account of the Fees Reduction Fund. The sale of the Acton estate has not yet been completed, but a deposit is in hand, and a half-year's interest on the balance has been received.

The Charitable Trusts Bill, which was introduced into Parliament last session, and which would have affected our interests had it not been for a clause introduced by our Fellow the Marquis of Salisbury, specially exempting the Royal Society from its operation, was withdrawn.

The collection of portraits in the possession of the Society has been enriched by the addition of a portrait of Sir Joseph Dalton Hooker, painted by John Collier, Esq., at the expense of a considerable number of our Fellows, who were desirous of expressing their sense of the important services rendered by Sir Joseph to the Society, and at the same time of securing a permanent memorial of their late President. It is to be hoped that advantage may be taken of any suitable occasions that may arise from time to time of adding to our gallery of historical records of the great men whom we have reckoned among our Fellows.

The Fellows will learn with satisfaction that the first part of the new edition of our library catalogue is published. This part, consisting of 232 pages, contains the Transactions, Proceedings, and Journals published by Societies and Institutions in nearly all parts of the world;

and also the observations, reports, and accounts of surveys which are to be found in our library. As our Library Committee has always devoted great attention to securing by exchange or by purchase publications of this class, and as the main strength of our library consequently lies in our collection of them, the part in question will form the most important section of the entire catalogue.

Progress has also been made in the more voluminous portion of the catalogue, viz., that of the general collection of scientific books, of which thirteen sheets, extending to the letter C, are printed off, or are in type. It may fairly be hoped that before our next anniversary the whole will be published.

The last part of the Philosophical Transactions for 1880 was published in March of the present year, completing a volume of nearly 1,100 pages, with upwards of fifty plates. Of the Transactions for 1881, Parts I and II have already appeared; from which an early publication of Part III may be anticipated.

Of the Proceedings, vol. 31 was published in June, and vol. 32 at the end of October.

Although, as I remarked last year, we are more concerned with the quality than with the quantity of the communications made to the Society, it may still be interesting to carry on the table of the number of papers presented per annum to a tenth year. It stands as follows:—

1872	..	..	99	papers	received.
1873	..	..	92	"	"
1874	..	..	98	"	"
1875	..	..	88	"	"
1876	..	..	113	"	"
1877	..	..	97	"	"
1878	..	..	110	"	"
1879	..	..	118	"	"
1880	..	..	123	"	"
1881	..	..	127	"	"

These 127 papers include one from Mr. Brooks of Baltimore, two from Professor Helmholtz, and one from Captain Mannheim, of the École Polytechnique, Paris. On reference to the papers themselves it will be noticed that several prominent men are carrying on with vigour the series of researches on which they have been, in some cases for years, engaged. Among them there may be mentioned, in physics, those of Professors Liveing and Dewar, and of Mr. Lockyer, on the Spectra of Terrestrial Substances and of the Sun; those of Professor Hughes on minute Interactions of Electric Currents and Magnetism; those of Mr. Crookes on High Vacua; and those of Mr. H. Tomlinson on the effect of Stress and Strain on the action of Physical

Forces. Mr. G. H. Darwin continues his already classical memoirs on the mechanical history of the solar system; and Captain Abney has opened out to view, by photographic means of his own invention, a part of the spectrum of the sun and of other bodies, beyond the red, hitherto invisible; and last, but not least, Professor Tyndall in his Bakerian Lecture has given an account of his researches on the action of free Molecules on Radiant Heat, and its Conversion thereby into Sound. In Biology, I may mention the investigations of Mr. Romanes on nerve systems; those of Professor Ferrier on the connexion between special portions of the brain and special motor organs of the animal system; those of Mr. Parker on the Skull of the Batrachia, and of Professor W. C. Williamson on the fossil plants of the Coal-measures. Among the newer subjects, the experiments of Dr. Young and Professor George Forbes on the velocity of light of different colours have naturally arrested considerable attention, for several reasons and especially because the conclusions thence deduced, if ultimately established, would fundamentally modify our views of the constitution of the luminiferous ether.

For several years past I have been able with much satisfaction to report that there had been no change in the staff of officers of the Society. I much wish that I could have done so again. But the longer a capable man lives and is available, the more will work accumulate on his hands; and the time at last comes when something must be given up, lest, in the multiplication of avocations, powers which might otherwise have been devoted to some great and good purpose, and on operations not within the grasp of everyone, should become dissipated among a variety of objects. A feeling that life must not be spent merely in running hither and thither, and a desire that it should be something better than a mere feat of mental agility exhibited in passing rapidly from one occupation to another, doubtless operated in leading Sir Joseph Hooker to resign the Presidentship; and a similar feeling has recently led to the resignation of the Secretaryship by Professor Huxley. That this loss is great will be felt by every Fellow of the Society; it will be more keenly felt by his brother Secretaries and the Treasurer, but most of all by your President. Connected as I have been with him through a series of years by ties of office in the Society, by bonds of friendship and trust as thorough as can exist between man and man, I cannot but miss for a long time to come his ever willing support, his sound counsel and advice, and the cheery manfulness with which he would always address himself to any business however difficult, uninviting, or heavy.

The post is one which it is not easy to fill. Many qualifications go to make up a good Secretary; and although none of us so "despaired of the republic" as to doubt that a good successor would be found, we still felt some anxiety until we were in a position confidently to recommend a name for your consideration. Professor Michael Foster's great scientific attainments, his administrative powers as shown in founding the great School of Biology at Cambridge, the confidence with which he inspires all around him, alike point him out as a man eminently fitted for the post. It would indeed have been agreeable to your President to have had one of the principal Secretaries resident in London; but the means of communication are now so different from what they formerly were, that questions of distance almost disappear; and it is certainly not without its advantages that the two principal Secretaries, if not resident in London, should reside in the same city.

In the course of the spring of the present year, Sir Joseph Copley, the present representative of the Founder of the Copley Memorial, explained in a visit to the President his wish to "provide in perpetuity a yearly bonus of £50, to be given to the recipient of the Copley Medal." As the donor's views on the terms of the gift were completely made up, and were not offered for discussion by the Society, or otherwise open to modification, the Council decided to accept the offer in the spirit in which it was made, and on the terms prescribed. In accordance with this, Sir Joseph transferred a sum in Consols sufficient to provide for the bonus proposed. This acceptance will not in any way affect the adjudication of the Medal, nor, it is to be hoped, the high estimation in which that award has always been held.

The period of five years during which the experiment of the Government Fund of £4,000 per annum was to be tried, has now expired. In a former address I have expressed opinions gathered from many of the Fellows of the Society, and have indicated my own. The President and Council have now, at the request of the Department of Science and Art, through which the vote is made, drawn up a report on the question, based upon the experience gained up to the present time, and have made suggestions with a view to a modified arrangement for the future. The Society will be duly informed of the result of those communications. In the mean time it may not be out of place to remind the Fellows that a statement of all grants made within the year is published in the report of our anniversary proceedings.

The Report of the Challenger Expedition, of which mention was made last year, is in the course of publication; and three volumes have now appeared. Copies of these have been presented by the Treasury to our library. Volumes II and III refer to the curious forms of life found in what Sir Wyville Thomson has called the "Abysmal Region," and are copiously illustrated with lithographs. The interest which attaches to this publication is evinced by the fact that the first edition of the second volume is already exhausted. A second edition of it is in the course of printing. The Fellows will doubtless have observed, that the printing of the text and the execution of the plates are maintained at the same high standard as that exhibited at the outset.

Among other scientific publications of the year, I may mention the third volume of Roscoe and Schorlemmer's work on Chemistry, Mr. Balfour's work on Comparative Embryology, and Mr. Darwin's on Vegetable Mould.

In December last the Council authorised the loan of the "Philosophical Transactions" from one of our complete sets, five volumes at a time, to the Delegates of the Oxford University Press, for the preparation of a Philological English Dictionary, under the editorship of Dr. Murray. It is hoped that this loan will contribute to the completeness of the work in respect of scientific terms. Forty-one volumes have been already utilised in this way.

Towards the close of last session a communication was received from the India Office enclosing a copy of a report and memorandum, on Pendulum Observations, by Major Herschel, and asking the advice of the President and Council thereon. Subsequently there followed another communication from the same office, enclosing a copy of a letter from the same officer, with an extract from a letter to him from Mr. Peirce of the United States Coast Survey. These documents were referred to a Committee consisting of Sir George Airy, Professor J. C. Adams, and Professor Stokes.

The Report of that Committee was forwarded to the India Office; the following extracts from it contain those parts which refer to the main scientific questions raised:—

"The object in referring these documents to the Royal Society was to assist the India Department in coming to a conclusion as to what, if anything, might yet be required in order to render the pendulum operations which have been carried out in connexion with the great trigonometrical survey of India reasonably complete as an important contribution towards the determination of gravity all over the earth.

"At present the stations which have been directly connected with the Indian stations are confined to Aden, Ismaïlia in Egypt, and Kew; and no one of these has been differentially connected with any of the chains of stations that have hitherto been used in the determination in this way of the figure of the earth, though Kew is now a station at which an absolute determination has been made. We think it would be a reasonable expectation on the part of the scientific public that the Indian group of stations, which have already been connected with Kew, should be differentially connected with at least one chain of stations which are so connected with one another, and which have been employed in the determination of the figure of the earth.

"We approve accordingly of the suggestion that gravity at Kew should be compared, by means of invariable pendulums, with gravity at another station belonging to another group. Greenwich has been named as such a station.

"In connexion with this subject, we would refer to the suggestion, which has been brought before us, made by Mr. Peirce, of the United States Coast Survey, that Major Herschel should swing the same two pendulums that were used in India, first at Kew and then at Washington.

"As Washington is, or shortly will be, connected differentially with a large chain of stations widely distributed in America and elsewhere, we think that the value of the Indian series would be decidedly increased by being connected with one of the American stations, such as Washington. We think, however, that its connexion through Kew with one of the older series should not on that account be omitted.

"The observations required for the purpose of these connexions are such as certainly can be made, and have been made, by existing methods; and the labour of making them, which will be approximately in proportion to the number of stations at which the pendulums will have to be swung, is only a fraction of that already incurred on the Indian stations, and the three which have been included in the same group with them."

In October last a letter was received from the Treasury asking the opinion of the President and Council respecting arrangements for observing the Transit of Venus in 1882. Under the advice of a Committee appointed for the purpose, it was recommended that a special Committee of the Royal Society should be appointed to decide upon the observations considered essential, and to advise Her Majesty's Government as to the best method of carrying them out. In conformity with this advice, and at the request of the Treasury, a Committee was appointed to draw out a scheme of stations, and of the constitution, strength, and equipment of the observing parties, and to frame an estimate of the total cost. The Committee reported recommending the adoption of certain stations in South Africa, the West Indies, Australia, and New Zealand, and the Falkland Islands; and they at the same time added other particulars, and furnished an estimate of the whole, adopting in the main the recommendations of that Committee; the Treasury then requested the President and Council to nominate an Executive Committee, by which (accounting to the Treasury) any vote of Parliament for the purpose of these observations might be administered; and under whose advice the observers and assistants might be selected and appointed. In compliance with this request the following Fellows were nominated as an Executive Committee, viz., the President, Professor J. C. Adams, Sir G. Airy, Mr. Hind, Sir G. Richards, Professor H. J. Smith, and Mr. Stone. That Committee is now continuing its labours, and has appointed its member, Mr. Stone, of the Radcliffe Observatory, Oxford, directing astronomer of the expeditions; and under him the selection of instruments, as well as the training of the observers, will be made.

With a view of making the observations ultimately as comparable as possible, the Committee, at an early stage, put itself, through the Foreign Office, into communication with the corresponding Commissions in foreign countries, on the subjects of the instructions to be given to the various observers; and a draft set of instructions, drawn up for this purpose, was circulated for comment and suggestion.

Moved perhaps in some degree by this action, the Government of France took advantage of the assemblage of scientific men collected in Paris for the Electrical Congress and Exhibition, to summon a Congress of Astronomers, having especially in view a consensus of arrangements for the observation of the Transit. This Congress met in Paris on the 5th of October, under the auspices of the Minister of Public Instruction. M. Dumas was appointed President; MM. Foerster and Weisse, Vice-Presidents; MM. Tisserand and Hirsch, Secretaries. The various countries of Europe were represented; but it was a matter of much regret that no representative from the United States of America was present. Mr. Stone attended on behalf of the British Committee. I must here express my regret at having been unable to attend in person to support our Directing Astronomer, who made the journey at much inconvenience to himself; but I should at the same time add that my absence in no way diminished the effectiveness of Mr. Stone's counsels, which proved of great service in promoting a unanimity in the views finally adopted by the Congress.

Two Committees were appointed (1) for the selection of stations; (2) for a discussion of methods of observation.

As the British stations had been already chosen and did not admit of material alteration, the first of these Committees did not directly concern us. But, judging from the number of observations contemplated to be made in South America by foreign expeditions, it seems not impossible that the party which we had proposed for the Falkland Islands might be advantageously transferred to some other locality, so as to strengthen the parties requiring support, for example, in Australia.

As regards the discussion of methods, the draft instructions drawn up by the British Committee, and especially the definition of contact to be observed, strongly insisted upon by Mr. Stone, were in the main adopted. The following are the principal points agreed upon:—

With a view to uniformity of method of observation, it is necessary that instruments of nearly the same aperture, 6 inches, should be used, also that the observations of contact should be made in a field of just sufficient brightness to allow of the clear separation of two threads at one second of arc apart when seen projected on the sun with a power of 150. The times corresponding to the internal contacts should be defined as follows :—

At Ingress.—" The time of the last appearance of any well-marked and persistent discontinuity in the illumination of the apparent limb of the sun near the point of contact."

At Egress.—" The time corresponding to the first appearance of any well-marked and persistent discontinuity in the illumination of the apparent limb of the sun near the point of contact."

It is a point of primary importance that all the observers shall, as far as possible, observe the same kind of contact; and it is therefore desirable that the times recorded for contacts should refer to some marked *discontinuity* in the illumination of the sun's limb about which there cannot be a doubt, and which may be supposed to be recognisable by all the observers. If a pure geometrical contact is alone seen, there can be no doubt about the time which should be given ; but, if haze is noted, it should be haze nearly as dark as the outer edge of the planet ; and if a ligament is seen, it should be nearly as dark as the outer edge of the planet.

A further proposal was made to establish a Central Bureau in Paris to receive and discuss the observations, and to enter upon other work more or less directly connected with the determination of solar parallax. But, as this question was not contemplated in the instructions given to our representative, and indeed exceeded the powers of the British Committee, no definitive resolution was passed on the subject.

On the subject of the longitude of a point in Australia, to which I made allusion in my address last year, as important for the observations of the Transit of Venus, I have lately received a letter from Mr. Todd, of the Observatory, Adelaide, from which the following is an extract: " With regard to the determination of Australian longitudes: as it is understood that Lieut.-Commander Green, U.S.N., will call at Port Darwin to determine its longitude by signals from Singapore on the one side, and with the Adelaide Observatory on the other, I have taken no further steps for going to Port Darwin as previously arranged. I shall take all the necessary observations here, and exchange signals with Lieut.-Commander Green over my overland telegraph; and, in conjunction with Messrs. Ellery and Russell, make fresh determinations of the difference of longitude between Adelaide, Melbourne, and Sydney."

Since our last anniversary, Sir George Airy, the late Astronomer Royal, having completed his eightieth year, and nearly half a century of office, has retired. Of his services to science, and to this Society as President, and in other ways, the time to speak has happily not yet arrived. His great intellectual powers are in fact in no way impaired, and so far from having brought his period of activity to a close, he hopes to employ his well-earned leisure in completing a favourite work, the Numerical Lunar Theory.

His successor, Mr. Christie, from his long experience in the Royal Observatory, will combine a thorough training in the remarkable organisation and methodical administration for which his predecessor was so conspicuous, with the full vigour of life, and an active interest in the more modern developments of astronomy, in which he is already distinguished.

The future of the Royal Observatory is a subject on which the mind of Sir George Airy often exercised itself, and to which he alluded more than once in his Reports to the Board of Visitors. With his fundamental proposition that, observational astronomy, in its bearing on the improvement of navigation, must always be its main line of work, every one must agree. Over and above this, the expressed wish of the Board of Visitors, and the practice of the last few years, have already sanctioned the addition to the ancient duties of the Observatory of some of those long and systematic series of observations, such as that of the solar protuberances, and the motion of the fixed stars in the line of sight as shown by the spectroscope, which are beyond the scope of an amateur, and above the power of any individual astronomer, however devoted to his work, to permanently maintain. How far it may be desirable to continue magnetic and meteorological observations beyond the necessities of an astronomical observatory, are questions which will doubtless engage the attention of the present director. The main question must be, what distribution of these branches of study among Greenwich, Kew, and other establishments, will in the end best conduce to the progress of science. And with a view of giving full scope to the judgment and skill of the present and future holders of the office the Board of Admiralty have, as I understand, decided to consider a revision of the terms of the Royal Warrant under which the appointment is made.

This year has been signalised by the meeting of a most important scientific congress—the International Congress of Electricians, held at Paris. The recent developments of the practical applications of electricity rendered the occasion favourable both for organising a special exhibition devoted solely to this branch of science, and also for assembling the electricians of all countries.

The general purpose of this Congress was to discuss, and, if possible, to settle, some of the numerous difficulties which perplex both the physicist in his studies and the constructor in his work.

But chief among the subjects proposed to, and undertaken by, the Congress was that of fixing a system of electrical measures for international adoption.

Perhaps in no subject is the necessity of uniform system of standards so striking as in electricity. This science, both in its practical applications, such as telegraphy, and in the great natural problems of terrestrial magnetism and atmospheric electricity, refuses to recognise any artificial divisions of the surface of the globe, whether ethnological or political. It rarely happens, in operations undertaken on so large a scale as the study of electricity and its industrial applications, that an opportunity presents itself of arranging for concerted and harmonious action through a period extending to a distant future. Before a branch of industry has attained sufficient importance to claim international recognition, it has usually gone through the process of considerable development in different countries; and in each of these developments it has often received a stamp of local character which makes it difficult to reduce the whole to one uniform system. But in the case of electricity there were fortunately present special circumstances which facilitated the adoption of uniform standards. Foremost among these was the fact that the development of its practical applications, in other departments than telegraphy, were so recent that it was not too late to legislate for it as though it were but just about to begin. Secondly, the international character of telegraphy, and the fact that the manufacture of its apparatus had always been confined to the great centres of civilisation, had both tended to limit the number of existing systems of measurement, and prevented that multiplicity of standards which would certainly have arisen had such manufacture been carried on in numerous and in isolated localities. But by far the most important influencing circumstance was the happy idea due to the British Association of adopting standards based on absolute measures. The Association did not allow the idea to remain barren; but, through the instrumentality of its Committee on Electrical Standards, it gave to the world the admirable units of the Ohm, the Volt, and the now re-christened Weber; and the eminent men who formed that Committee may now point with honourable satisfaction to the fact that the Electrical Congress decided unanimously to recommend for universal acceptance those units which that Committee so early adopted.

With the single exception of the unit of current which, in order to avoid an ambiguity in the signification of Weber, receives the title of Ampère, the names are left substantially without change.

The adoption of these units for international use is to be preceded by a new and more careful redetermination of the ohm at the hands of the great physicists of all nations. And it is intended that this redetermination shall result in a standard for general adoption. Thus electricity will be the first of the practical sciences to be freed from all difficulties due to local standards; and it is to be hoped that this example may be followed in other sciences concerned with practical life.

The following are the actual resolutions adopted by the International Congress of Electricians at the sitting of September 22nd, 1881:—

1. For electrical measurements, the fundamental units, the centimetre (for length), the gramme (for mass), and the second (for time), are adopted.

2. The Ohm and the Volt (for practical measures of resistance and of electromotive force or potential) are to keep their existing definitions, 10^9 for the Ohm, and 10^8 for the Volt.

3. The Ohm is to be represented by a column of mercury of a square millimetre section at the temperature of zero Centigrade.

4. An international commission is to be appointed to determine, for practical purposes, by fresh experiments, the length of a column of mercury of a square millimetre section which is to represent the Ohm.

5. The current produced by a Volt through an Ohm is to be called an Ampère.

6. The quantity of electricity given by an Ampère in a second is to be called a Coulomb.

7. The capacity defined by the condition that a Coulomb charges it to the potential of a Volt is to be called a Farad.

The remainder of the work of the Congress consisted mainly of the discussion of various interesting questions bearing upon electricity; and although these did not in many cases issue in precise recommendations, yet they were not altogether devoid of practical results. The questions which chiefly attracted its attention were those of terrestrial magnetism and earth-currents, atmospheric electricity, and the more practical but perplexing question of lightning conductors. In all these matters the need of close and continuous intercourse between the observers of different nations was strongly felt: and the Congress passed resolutions recommending combined action both in the way of observations carried on simultaneously and with like apparatus, and also of frequent if not continuous telegraphic communication of the results of these observations. The organisation of so extensive and perhaps so costly a system of combined observations must depend to a great extent on the various Governments, and also on the goodwill and generosity of the great telegraphic companies: but it is much to be wished for the sake of science, that some progress in that direction may soon be effected. The present state and prospects of electro-physiology also received careful discussion, but the difficulties of the subject precluded any definite conclusions. The same was the case with the question of photometry as applied to the intense light with which electricity furnishes us. Resolutions recommending the adoption of certain provisional photometric standards were passed: but these only evidenced the strong feeling that prevailed in the Congress, that some new departure must be made, and that a new standard of illumination (such as perhaps the glow of platinum on the point of fusion) must eventually be adopted for electric lights.

I have described the more important of the results of the deliberations of the Congress. Perhaps, however, the most important of all (with the exception of the choice of electrical units) will prove to have been the impetus given to electrical science by the interchange of ideas that took place among the leading physicists of all nations, and the light that was thrown on the various problems which came under discussion in the meetings of the Congress.

I cannot conclude this imperfect sketch of this important Congress better than by quoting the eloquent words of M. Dumas at the conclusion of its sittings:—"Greek mythology, in its happy personification of the forces of nature, placed the winds and the waves under the direction of divinities of the second rank; it made the celestial representative of light its god of poetry and of the arts; and by an admirable forethought, it reserved lightning for Jupiter. Science and industry have long since laid their hands on the forces which air and water have placed at the disposition of man. Steam, animated by fire, has enabled him to overcome many obstacles and to rule the waves. Light has no longer any secrets from science, and the arts are daily multiplying its marvellous applications. But there remained one labour to accomplish; namely, to wrest lightning itself from the hands of the ruler of the gods, and to bend it to the needs of humanity. This is the feat which the nineteenth century has now accomplished, and of which this Congress is the evidence and the witness. This feat will mark an epoch ever memorable in history; and, amid the turmoil of politics and of questions which agitate the human mind, it will be recognised as the characteristic feature of our era. The nineteenth century will be the century of electricity."

After the Congress, one of the most remarkable events during the present year has undoubtedly been the Electrical Exhibition in Paris. I do not of course purpose to describe it, as many of our Fellows visited it; and full descriptions have reached us through various channels. One point, however, must have struck those who examined any considerable number of the objects; and this I mention, not as in any way disparaging them, but rather as illustrating the stage to which electrical science has attained; namely, that while the assemblage of instruments and appliances was in every way remarkable, and while very great ingenuity and skill had been expended on their contrivance and construction, yet the amount of novelty in the principles involved was comparatively small. Of new combinations, improved methods, and adaptations in detail there was abundance. Some of them even removed former inventions from the category of curiosities to that of instruments for practical employment; or enlarged their sphere of utility from that of the laboratory to that of everyday use. But such is the mass of fruitful matter which science has furnished to the mechanician and constructor, that we might almost wish, from the point of view of the latter, that they may have time to work out more fully than has yet been done, the results of science, before they are called upon to elaborate any fresh materials.

It is now proposed to repeat as far as may be, this Exhibition, at the Crystal Palace; and the energy with which the proposal has been taken up, and the response with which it has met in many quarters, appear to justify sanguine expectations of its success, at all events from a practical and popular point of view. From the side of science, it would doubtless have been far more interesting to look forward to a fresh Exhibition, either here or elsewhere, of the progress of electricity after an interval of two or three years. But there is nothing in the present undertaking to interfere with the more advanced project, if, after some such period as that indicated, circumstances should prove favourable. In the meantime, it must be remembered that there are very many persons to whom the Paris Exhibition would have proved both interesting and instructive, but who, from one cause or another, were prevented visiting it. Besides this, there are not a few commercial, and even municipal, bodies desirous of adopting some of the modern applications of electricity, but who would be more ready to avail themselves of them after a personal inspection of the instruments and of their mode of action. From this point of view the Exhibition may fairly be expected to give considerable impulse to the adoption of electrical appliances in fresh quarters.

But even over and above this practical aspect of the undertaking, there may still have been at the epoch of the Paris Exhibition, some results on the eve of achievement, some remedies for defects, sufficient to transform a doubtful into a certain issue, or even a failure into a success; some steps which may open out new questions, or serve as a departure for new investigations in the subject of electricity. If such should be the case, even science may derive substantial benefit from the proposed undertaking.

But the present year has been rendered generally remarkable, amongst other things, by the multiplicity of its Congresses. Apart from those which are concerned with subjects not coming under the head of "Natural Knowledge," there have been held the annual meetings of the British Association, and of the Iron and Steel Institute; the International Medical Congress, in London; the special Congresses on Electricity and on the Transit of Venus, in Paris (mentioned above); that on Geography in Venice; that on Geology in Bologna, and others.

Among all these, the International Medical Congress which this year met in London, stands conspicuous. The work of that meeting showed that the study of medicine by the real workers is, in every part, even the most practical, pursued in a thoroughly scientific spirit; that facts are industriously collected, and patiently grouped and compared; and that conclusions are, if sometimes hastily drawn, yet very cautiously accepted. And there was ample evidence that help, whether in apparatus or in knowledge, is eagerly accepted from all the other sciences whether their range be far from, or near to, the biological. In short, in the opinion of those best qualified to form a judgment, it is not too much to say that the whole tone of the proceedings of the Congress, though chiefly concerned with practical questions, was, in the best sense, even in the sense which the Royal Society would give to the term, scientific.

Several of the societies meeting annually, or at longer periods, have organisations which, during the intervals between two successive meetings, do useful work. But in all cases the meetings form the most prominent, if not the most important feature of their life; and, speaking particularly of the meetings themselves, the question has more than once been raised whether they continue to justify the efforts necessary to bring them about. It has been argued that, so many are the scientific periodicals in every civilised country, that all the papers of importance communicated to the meetings would under any circumstances be published in some place or other. Again, it has been urged that, so numerous are the centres of science, so many the means of communication both between places and between persons, that the necessity for these gatherings has, in the natural course of events, become superseded. The time which such meetings and the preparation for them involve, and the trouble which they entail on men already burdened with much work, have also been pleaded on the same side, and objections have been taken on the ground of the useless and irrelevant matter which is too apt to crop up on these occasions. These arguments are certainly not without weight; but there is still another side to the question. It is, indeed, quite probable that all the more important papers would be published even if the meetings never took place at all. But at these meetings there are usually a number of communications, many, but not all, of local origin, the production of which has been stimulated by the meeting itself; and a fair number of these may be reckoned on the side of gain. Again, it is true that the original idea of a parade or march past of science, valuable enough when the provinces heard or saw little of science, has become less important now that provincial centres are to be found in almost every large town in the country. Nevertheless, the mere presence of some of the leading men stimulates dormant powers and encourages rising aspirations; and this perhaps all the more the case for the very reason that science and scientific names are no longer unknown. That most of the leading men have opportunities of meeting from time to time, and for scientific purposes, is certainly true; but that they should meet also on occasions when science is not too formal, is a thing which has its uses. And a concurrence of minds more numerous and more diversified than usual is sure to be fruitful of results. The whole advantage of these meetings, however, depends ultimately and fundamentally on the presence of a strong scientific element, which, from its own mere dignity and character, will repress all that is unworthy and will leaven the whole lump. Acting on this principle as a scientific duty, many good men have attended these meetings; and although they may have approached them with some degree of reluctance, few who during their attendance have taken their fair share in the proceedings, have come away without having derived a more favourable impression than that with which they entered.

Of such gatherings, the late meeting of the British Association at York was, if I may be permitted to express an opinion, a pattern and exemplar. And although it cannot be expected that in every year there will be so strong a muster as on the occasion of the fiftieth anniversary, yet all well-wishers of the Association must feel that it has entered upon its second half century with vigour and with dignity, and that it now remains only for its future supporters to maintain the high standard with which it has been handed down by those who have gone before.

It may be a matter of regret, although doubtless inevitable, that the same causes which have affected the social, the intellectual, the industrial, and the political life of our generation, and have made them other than what they were, should affect also our scientific life; but, as a matter of fact, if science is pursued more generally and more ardently than in former times, its pursuit is attended with more haste, more bustle, and more display than was wont to be the case. Apart from other reasons, the difficulty, already great and always rapidly increasing, of ascertaining what is new in natural science; the liability at any moment of being anticipated by others, constantly present to the minds of those to whom priority is of serious importance; the desire to achieve something striking, either in principle or in mere illustration; all tend to disturb the even flow of scientific research. And it is perhaps not too much to say that an eagerness to outstrip others rather than to advance knowledge, and a struggle for relative rather than for absolute progress, are among the dangerous tendencies peculiar to the period in which we live. I do not, of course, for one moment mean to imply that this tendency universally prevails; for in Science, as well as in other pursuits, I believe that the best of the present would well stand comparison with the best of the past, and that there are nowadays men in the mid-stream of life who are as little affected by the eddies and back-waters with which they are surrounded as were the giants of former days. Nevertheless the danger is a real one and is to be met with at every turn.

But the part of Cassandra is neither agreeable to the player nor welcome to the audience; nor is it indeed necessary that I should play it; for, even although what I have said be true, it is still, I trust, not the whole truth. I have already spoken of noble exceptions; but, although noble exceptions may go far to redeem the character of a nation or of a period, and example may have influences of which we hardly dream, yet for a general remedy I am more inclined to look to the natural course of events, and to what is often loosely spoken of as "things curing themselves." Such a cure may perhaps come about somehow on this wise. So multitudinous are the workers in every science, so numerous are the channels through which their discoveries are chronicled, that it is becoming every year more difficult for even the learned and the well read to say what is and what is not new, or what has not been published before. Claims for novelty must, therefore, as time goes on, be put forward with greater and greater diffidence. The only originality that can be safely claimed will be originality on the part of the investigator; and the question of absolute priority must be left to the verdict of time and of that sifting process by which ultimately all discoveries will find their proper places in the Temple of Science.

When this stage is reached, and we are even now approaching it, the fever of to-day may in a great measure subside and give place to a more tempered, although still fervent, glow of aspiration. The eagerness and haste to which we have become almost accustomed may be chastened by the reflection that questions of priority are not to be settled by a mere stroke of the pen, and that in the comparison of rival claims the question of the quality of work will undoubtedly arise and become interwoven with that of priority. And so, in the end, it may come to pass that a half-understood experiment or a hastily drawn conclusion may avail less than ever for establishing a reputation, and that, even for the purpose of winning the race, it may be worth while to spend sufficient time in laying sure foundations and in building a superstructure commensurate with that on which it stands and well proportioned in all its parts.

The transference of the Natural History Collections of the British Museum to the new building at South Kensington is still in progress. It is hoped that the building for the specimens preserved in spirits, as well as the fittings for the zoological department, will be so far completed as to allow of the moving of that department during the autumn of 1882. The lighting of the reading room by Siemens' lamps is so far satisfactory, that it has been decided to keep that room open in future until 8 P.M., instead of 7 P.M. This change, it is hoped, will prove to be of substantial service to a large class of readers.

The Institution founded in 1851, under the title of the Government School of Mines and Metropolitan School of Science applied to Mining and the Arts, for the instruction of students in those branches of Science which are indispensable to the Miner, the Metallurgist, the Geologist, and the Industrial Chemist, has this year been organised afresh, and, under its new title of the Normal School of Science and Royal School of Mines, adds to its former functions the training of teachers for the Elementary Science Classes under the Science and Art Department, the multiplication of which, in recent years, is a significant indication of the rapid spread of scientific instruction throughout the country.

The accommodation requisite for practical teaching being inadequate in all cases and totally wanting in respect of many of the classes, in the Museum of Practical Geology in Jermyn Street, and in the Royal College of Chemistry in Oxford Street, all the instruction, except that in Mining, has been transferred to the Science Schools at South Kensington. The staff of Professors and Lecturers has been increased, and provision has been made for the teaching of various important subjects, such as Mathematics, Drawing, Botany, and the Principles of Agriculture, which were either omitted, or insufficiently represented, in the original programme of the school.

Under its new organisation, the Normal School of Science and Royal School of Mines will not merely supply from among its associates persons highly qualified to apply the principles of science to the Mining, Metallurgical, Chemical, and Agricultural industries of the country, and properly trained science teachers; but, through the exhibitions attached to the yearly examinations of the Science and Art Department, it will place within reach of promising young students in all parts of the country, whose means do not enable them to obtain the benefits of a University education, such a training as will enable them to turn their natural abilities to account for the advancement of science and the improvement of its applications to industry. Under the latter point of view, the instruction given in the Normal School of Science will lead up to the special technical training of the Central Institute of the Guilds of the City of London.

Under the auspices of the City and Guilds of London Institute, further progress has been made during the past year in the promotion of Technical Education. It will be remembered that the work at present undertaken by the Institute embraces the establishment of a Technical Science School in Finsbury, a Technical Art School in Kennington, a Central Institution or Higher Technical College in Kensington, the subsidising of existing institutions, affording facilities for Technical Instruction and the encouragement of existing classes in the manufacturing centres by the grants paid to teachers on the results of the Technological Examinations.

In May last the foundation stone of the Finsbury College was laid by H.R.H. Prince Leopold, and the new building, which will afford accommodation for the teaching of applied Chemistry, Physics, and Mechanics, will be finished early in next year. Notwithstanding the inadequacy of the present temporary accommodation, large numbers of students have availed themselves of the instruction afforded. The principles of Electric Lighting and Transmission of Power, the making of Electrical Instruments, Coal Tar, and Spirit Distilling have been the subjects that have been chiefly studied during the past session.

Since October the classes that were previously conducted by the Artizans' Institute have been transferred to the Finsbury College.

The Institute has under its consideration the establishment of a School for Applied Art in connexion with the Finsbury College. Acting on the general principle that every Technical School of this kind ought to provide, in addition to the general course of instruction, as applicable to different industries, special courses applicable to the staple industry of the district, the Council of the Institute are contemplating the establishment of classes in the Finsbury College adapted to the educational requirements of those engaged in Cabinet-making. With this object it will be necessary to attach a School of Design to the College.

The influx of pupils to the studios in Kennington have induced the Council to vote a sum of money for the extension of the building in which the Art School of this district is conducted. These new buildings are nearly completed, and will afford accommodation for classes in Modelling, Design, and Wood Engraving.

The building of the central institution, which is to be in the first place a school for the training of technical teachers, has been commenced. The first stone was set in July last by H.R.H. the Prince of Wales, who is now the President of the Institute. The plans of this building show accommodation for the teaching of the different branches of Physics in their application to various industries, of Chemistry as applied to trade purposes, and of Mathematics and Mechanics in their application to Engineering. A good engineering school, containing workshops, well supplied with machinery and collections of mechanical instruments and models, such as exist in numerous Continental cities, seems likely to be obtained for London on the completion of this building.

This Institute has done much towards the encouragement of technical instruction in provincial towns, where it is most needed, by its system of annual examinations. In the examination held in May last 1,563 candidates presented themselves, in 28 subjects, from 115 centres, and of these 895 passed. A close connexion is being established between the several technical schools which are being now opened in Lancashire and Yorkshire, and the City and Guilds of London

Institute. The demands made upon the Institute by Chambers of Commerce in different parts of England satisfactorily indicate the usefulness of this part of the Institute's work.

The programme of Technological Examinations for 1881–82, just issued, shows 32 subjects in which examinations may be held, some of which are divided into four or five branches, so that they may be better adapted to individual industries. Whilst attention has in this way been given to the details of different trades, the attempt has been made to secure from candidates passing the Institute's examinations a general knowledge of the principles of their subject and of the relation of closely connected industries with one another.

In order to secure in future efficient teachers, the Council of the Institute have determined after March next not to register as teachers any persons except those who have passed the Institute's Honours Examination, or such as already possess special or distinct qualifications.

The interest which the subject of technical education is beginning to arouse has led to the appointment by the Crown of a Commission to inquire into the education of the industrial classes in England and in other countries; and the City and Guilds of London Institute is represented on this Commission by Professor Roscoe, who, as President of the Chemical Society, occupies a seat on the Executive Committee, and also by Mr. Philip Magnus, its director and secretary. The Commissioners are at present engaged in making a tour of inspection in France, a section of them having already visited some of the principal technical schools and factories in the north of Italy.

In Meteorological Science the present year has been marked by the publication of an important work,* by Professor Wild, of St. Petersburg, on the Temperature of the Russian Empire, embodying, in charts and tables, a great amount of information, hitherto either inaccessible or existing only in scattered memoirs, relating to the meteorology of the vast tracts of Northern Asia. As an interesting particular result it may be mentioned that Professor Wild has transferred the "Siberian pole of cold in winter" from the neighbourhood of Jakutsk to a point somewhat further north, lying on the Arctic Circle in (about) E. longitude 125°. At this centre of maximum cold, round which the isotherms lie in fairly regular ovals, the mean temperature in January sinks as low as $-54°$ Fahrenheit, the mean temperature at Jakutsk being 11° higher. In close relation to the phenomena exhibited by these charts, Professor Wild, in St. Petersburg, has been led to study the connexion between areas of permanent high or low mean pressure on the one hand, and areas of permanent high or low mean temperature on the other; and he has found this

* "Die Temperatur Verhältnisse des Russischen Reichs," St. Petersburg, 1880.

connexion to be of the same kind as that known to exist in the case of the shifting areas of high or low pressure, and high or low temperature, which determine the changes of weather. M. Léon Teisserenc de Bort, in Paris, has also investigated the same subject.

The Meteorological Office has completed during the year two works of some interest, which are now ready for immediate publication. The first consists of tables of the Rainfall of the British Isles, prepared at the request of the Council of the Office by Mr. G. J. Symons, F.R.S. These tables include the monthly results recorded at 367 stations in the United Kingdom, being all those for which it was possible to obtain series of observations maintained continuously during the last fifteen years. The second is a volume of charts (with an introduction and explanations) illustrating the meteorology of an ocean district specially important to seamen—that adjacent to the Cape oc Good Hope. Some points of novelty are presented by the charts. For example, a new form of "wind-rose," invented by Mr. F. Galton, F.R.S., has been employed, which offers some theoretical advantages over those previously in use, being intended to represent, with geometrical precision, the probability (deduced from the observations) that, in a particular place and at a particular season, a wind blowing between any two given points of the compass will be experienced. Again, for the first time in marine meteorology, the wind observations have been "weighted" with the view of neutralising the tendency to over-estimate the frequency of adverse winds, which has been found to affect meteorological charts injuriously. The work brings into clear relief the most interesting physical feature of the district—one indeed already well known—the intermingling of hot and cold water, brought by the Agulhas and the South Polar currents respectively, and supplies strong evidence for the belief that this intermingling has a large share in producing the atmospheric disturbances so common in the region in which it occurs.

In my Address to the Society in 1879, I stated that an International Conference of a semi-official character had been held, with the view of establishing for one complete year a circle of meteorological observations round the Arctic regions of the globe. Notwithstanding the lamented death of Lieutenant Weyprecht, the gallant young discoverer of Franz Josef's Land, by whom the proposal had been originated, it would seem that the efforts of the Conference are likely to be crowned with success. The following stations have already been undertaken by different Governments: Point Barrow and Lady Franklin's Bay in Smith's Sound, by the United States; West Greenland, by Denmark; Jan Mayen, by Austria; Mossel Bay and Spitzbergen, by Sweden; Bossekop, by Norway; Nova Zembla, by Holland; the Mouths of the Lena, by Russia. The Conference has also been led to hope that the Canadian Government may reinstitute observations at Fort Simpson, and that the Government of France may organise a simultaneous meteorological expedition to Terra del Fuego. It is arranged that the observations should begin as soon as possible after August 1, 1881, and should continue to September 1, 1883.

In astronomy, Mr. Gill has completed his discussion of the extensive series of heliometer measures of the parallax of Mars, which he made at Ascension in 1877, and has deduced the value 8″·78 for the solar parallax, corresponding to a mean distance of 93,080,000 miles from the earth to the sun. A value of the solar parallax has also been derived by Mr. D. P. Todd, from the American photographs of the transit of Venus, 1874. The result for the parallax is 8″·883, corresponding to a mean distance of 92,028,000 miles.

A valuable contribution towards the determination of the moon's physical libration has been made by Dr. Hartwig. From a series of 42 measures made with the Strassburg heliometer he derives values for the physical libration and for the inclination of the moon's axis, substantially confirming the results found by Wichmann, and recently by Professor Pritchard.

An addition to the small list of stars which have been found to have a measurable parallax, has been made by Dr. Ball. He finds that the star Groombridge 1618, which is remarkable for its large proper motion, has a parallax of about one-third of a second, so that it is to be considered one of the sun's nearest neighbours. Dr. Ball has also redetermined the parallax of the double star 61 Cygni, his result being 0″·468, which agrees more nearly with Struve's value than with Bessel's.

The Cape catalogue of upwards of 12,000 stars is the outcome of Mr. Stone's labours during nine years, as Her Majesty's Astronomer at the Cape, and is the most important catalogue of stars which has yet been formed in the southern hemisphere. Another important contribution to stellar astronomy has been made by Professor Newcomb, who has recently prepared a catalogue of the places of nearly 1,100 standard stars compiled from the best authorities.

In connexion with his photometric researches, Professor Pickering has discussed the causes of the variability of stars of short period. Taking the various hypotheses which have been proposed, he finds that for Algol and stars of that type the hypothesis of an eclipsing satellite or cloud of meteors revolving round the star is the only one which satisfies the observed phenomena. In the case of β Lyræ and similar variables the fluctuations of light would be explained as due to rotation round the axis, the two hemispheres being of unequal brightness and the form more or less elongated. Professor Pickering has very carefully investigated the conditions in each individual case, and has brought together the most important facts bearing on the subject. It may be mentioned that on Professor Pickering's initiative a committee of American astronomers has been formed to co-operate with European astronomers in selecting a series of stars to serve as standards of stellar magnitude.

The present year has been remarkable for the appearance of two bright comets simultaneously visible to the naked eye. The first comet was first seen in the southern hemisphere before its perihelion passage, and burst upon our view in its full splendour soon after perihelion. The most important point in connexion with this comet was that photographs of its spectrum were obtained by Dr. Huggins and Dr. Draper. The former found on his photographs two strong bright lines in the ultra-violet corresponding to a group in the spectra of compounds of carbon, and also a group of lines between G and *h* agreeing in position with another carbon-band. The photographs also showed a continuous spectrum extending from F to some distance beyond H, on which the dark Fraunhofer lines were seen—an indication that part of the light from comets is reflected solar light.

In the visible portion, the continuous spectrum was so bright when the comet was first seen after perihelion that it almost obliterated the ordinary cometary bands. These, however, became afterwards very conspicuous, and five bands were noted, which were found to coincide sensibly with the carbon-bands as given by the flame of the Bunsen burner. On the brightest band, three bright lines corresponding to three lines in the carbon-band were seen by several observers at Princeton, U.S. These observations show conclusively that the spectrum of this comet is identical with the first spectrum of carbon, and not with the second.

In the telescope this comet showed striking changes from day to day, and even, according to some observers, from hour to hour, and the head was remarkable for its unsymmetrical appearance. Another point of interest is that the orbit presents a remarkable resemblance to that of the great comet of 1807. As, however, the period of this latter was found by Bessel to be 1540 years, the question arises again, as in the case of the comets of 1843 and 1880, whether there are not two comets travelling along the same path.

The second bright comet was first discovered with the telescope, and gradually increased in brightness till it became visible to the naked eye, though by no means so interesting an object as the preceding comet. Besides these two bright comets, several telescopic comets have been discovered, raising the total for this year to eight. The last but one of these has proved to be a periodic comet, revolving in the short period of about eight years. It was discovered by an Englishman, Mr. Denning, being the first instance of such a discovery in this country for many years.

The work of the Royal Commission on Accidents in Mines during the past year has been of such great interest, both from a scientific and from a practical point of view, that I venture to note at length some notes upon it, furnished to me by our Fellow, Mr. Warington Smyth, the Chairman.

A preliminary report was presented before the end of the Session 1881, drawing attention, under the chief heads of the subject, to the facts and opinions elicited from the examination of a large number of competent witnesses.

Experimental inquiries, which will be the subject of a further report, have been instituted for the purposes of testing the various safety-lamps in use, as well as the numerous modifications recently proposed, and of determining the effect of coal-dust in causing or aggravating explosions. From time to time, also, experiments have been made with a view to substitute, in the breaking down of coal, some other means for the gunpowder-shots which have so often, by their flame, caused the ignition of fire-damp.

The presence of a powerful "blower" of natural gas at the Garswood Hall Colliery, near Wigan, with the facilities offered by the proprietors, induced the Commission to erect suitable apparatus for a long series of these trials, and now that it appears desirable to compare the results with what may be obtained in another district, and with a differently constituted fire-damp, the whole of the apparatus is in course of erection at a colliery in the Rhondda Valley, where a very permanent "blower" offers similar advantages.

In the course of the lamp experiments it came out very clearly, in confirmation of statements before made, that the greatly augmented ventilation in our larger modern collieries has put an end to the fancied security of the simple Davy and Clanny lamps. Their use in fact, unless they be protected by some farther contrivance, is attended with the most imminent risk when the velocity of a current liable to be rendered explosive, exceeds six feet a second. A high degree of importance thus attaches to the comparative trials of lamps in which the flame is sufficiently shielded against the impinging stream of air, and those which have the property when immersed in an explosive mixture, of rapidly quenching both the flame of the wick and of the burning fire-damp.

The terrible disaster which occurred in September, 1880, at the Seaham Colliery, drew more anxious attention than ever to the question of the part played by coal-dust, and a special reference having been made by the Secretary of State for the Home Department to Professor Abel, C.B., the experiments at Garswood Hall were largely extended. Some of the results were very remarkable; the proportion of fire-damp present with the air may be so small as to elude detection by the ordinary test of the carefully watched flame in the safety-lamp, and yet the presence of dust in suspension will cause rapid ignition, or even explosion, in a degree varying with the proportion of gas and the velocity of the current. Dust was employed from different parts of the works of several collieries where it was suspected that this agent had borne a serious part in intensifying and spreading explosions; and it was found that some of the varieties were far more sensitive than others. Certain kinds of dust, in themselves perfectly non-combustible, were similarly tested, and proved to have an analogous effect in promoting explosion, even when the percentage of gas was exceedingly small.

It is obvious from these facts that under certain conditions it is very important that a satisfactory indicator of minute proportions of fire-damp should be employed; and the further experiments proposed to be carried out by the Commission will include a particular inquiry into this subject.

The question of the feasibility of the introduction of the electric light into the workings of a colliery has been partially solved. The Stanton Coal and Iron Company were induced by the Commission to make a trial of Mr. Swan's lamps in their Pleasley Colliery near Mansfield. Not only the inset and main road, but some of the "long-wall" faces of work, were brilliantly lighted in this manner. A second experiment of the same kind has been carried out at the Earnoch Colliery near Hamilton.

The use and abuse of explosives in mining operations has in the last few years formed a subject of much inquiry, especially with reference to the firing of shots in coal-seams liable to be invaded by fire-damp. A return to mere wedging in all cases, as proposed by some officials, would be to ignore the advance of science as well as the necessities caused by competition; and the Commission hopes by further examination, and especially by practical trials, to contribute useful information to the solution of a difficult but important question.

Among the applications of scientific apparatus, the employment of the ingenious protected lime-light lamp, and of the portable breathing arrangement of Mr. Fleuss, during the operations for re-opening of parts of the Seaham Colliery, deserves especial notice.

On the motion of Sir Frederick Bramwell, seconded by Dr. Allman, it was resolved :—"That the thanks of the Society be returned to the President for his Address, and that he be requested to allow it to be printed."

The President then proceeded to the presentation of the Medals :—

The Copley medal has been awarded to Professor Karl Adolph Wurtz, For. Mem. R.S. Professor Wurtz has, for many years past, been one of the most distinguished leaders of the progress of chemistry, and is now the most eminent of active French chemists. The younger generation of French chemists were, for the most part, his pupils. His writings have been the medium by which most of the knowledge of the more modern theories of chemistry has been disseminated in France. His discoveries have been fruitful of the greatest results, not merely in the way of enriching the science with a knowledge of many previously unknown compounds and classes of compounds, but more especially in extending and improving our knowledge of the laws of chemical combination.

It was he who first discovered compound ammonias containing alcohol-radicals in the place of hydrogen—a family of compounds which has since acquired enormous development. It was he who first made those remarkable alcohols called glycols, and thus gave the key to the explanation of glycerine, erythrite, mannite, and the sugars. Many other discoveries of his might be quoted; but those who know the influence which these two have exercised on the progress of chemistry can feel no doubt that the author of them is deserving of the highest scientific honour.

A Royal Medal has been awarded to Mr. Francis Maitland Balfour, F.R.S. Mr. F. M. Balfour's investigations in embryology and comparative anatomy have placed him, thus early in life, in the front rank of original workers in these branches of science. His "Monograph upon the Development of Elasmobranch Fishes," published in 1878, embodies the results of several years' labour, by which quite a new light has been thrown upon the development of several important organs in the Vertebrata, and notably of the genito-urinary and nervous systems. More recently Mr. Balfour has published a most important work on "Comparative Embryology" in two large and fully illustrated volumes, which stands alone in biological literature, not only as an admirable and exhaustive summary of the present state of knowledge respecting the development of animals in general, but by reason of the vast amount and the varied character of the original researches which are incorporated in its pages.

A Royal Medal has been awarded to the Rev. John Hewitt Jellett, F.R.S., Provost of Trinity College, Dublin. Dr. Jellett is the author of various papers on pure and applied mathematics; but the award is more directly connected with his invention of the analyser, known by his name, and for the elaborate optico-chemical researches which he has made with it.

This analyser was introduced by its inventor into the instrument by which he has carried on his researches on the state of combination of mixed solutions, as evidenced by the changes in their power of rotating the plane of polarisation consequent upon a change in the proportion of the active ingredients which enter into the solution. This is a problem towards the solution of which ordinary chemical methods can contribute but little. A single instance will suffice to give an idea of the nature of the results. It is known that quinine forms with many acids two series of salts, one having twice the quantity of acid of the other for the same quantity of base, while with other acids only the less acid salt has been obtained; so that the ordinary chemical methods fail to give evidence of the existence of the more acid salt. Now, by examining the rotatory power of a solution of a given quantity of base with different doses of acid, Dr. Jellett was able to obtain evidence of the existence of two, and but two, salts of the base, no matter whether the acid were or were not one which yields two crystallisable salts. A slight deviation in the amount of rotation when the more acid salt began to be formed in tolerable quantity, from what it ought to have been, on the supposition that the whole of the acid introduced was combined with the quinine, was naturally attributed to a slight partition of the acid between the base and the solvent, regarded as a feeble base; but the smallness of the deviation indicated that a solution of the more acid salt mainly existed as such, and that it was not, as some had supposed, decomposed into free acid and the less acid salt.

The Davy Medal has been awarded to Professor Adolf Baeyer, who was already known as the author of many masterly researches in organic chemistry, among which those on uric acid and on mellitic acid deserve special mention, before his latest and most remarkable discovery. The process for the artificial formation and manufacture of indigo is the result of long-continued efforts, directed by singularly clear and accurate views of the order and mode of combination of its constituent elements, and of the conditions requisite for obtaining reactions indicated by theory.

The Statutes relating to the election of Council and Officers were then read, and Mr. Kempe and Mr. McLachlan having been, with the consent of the Society, nominated Scrutators, the votes of the Fellows present were taken, and the following were declared duly elected as Council and Officers for the ensuing year:—

President.—William Spottiswoode, M.A., D.C.L., LL.D.

Treasurer.—John Evans, D.C.L., LL.D.

Secretaries.—{ Professor George Gabriel Stokes, M.A., D.C.L., LL.D.
Michael Foster, M.A., M.D., LL.D.

Foreign Secretary.—Professor Alexander William Williamson, Ph.D., LL.D.

Other Members of the Council.

Francis Maitland Balfour, M.A., LL.D.; I. Lowthian Bell, F.C.S.; Sir Risdon Bennett, M.D.; Professor Thomas George Bonney, M.A.; Professor Heinrich Debus, Ph.D.; Alexander John Ellis, B.A.; Sir John Hawkshaw, M.I.C.E.; Thomas Archer Hirst, Ph.D.; William Huggins, D.C.L., LL.D.,; Professor Thomas Henry Huxley, LL.D.; Professor Joseph Lister, M.D.; Professor Daniel Oliver, F.L.S.; Professor Henry Enfield Roscoe, B.A., LL.D.; Warington W. Smyth, M.A.; Henry Tibbats Stainton, F.G.S.; Edward James Stone, M.A.

The thanks of the Society were given to the Scrutators.

The following Table shows the progress and present state of the Society with respect to the number of Fellows:—

	Patron and Royal.	Foreign.	Com-pounders.	£4 yearly.	£3 yearly.	Total.
Nov. 30, 1880 ..	4	47	236	225	25	537
Since Elected ..		+ 4	+ 1	+ 2	+ 14	+ 21
Since Compounded			+ 1	− 1		
Since Deceased ..		− 1	− 11	− 12		− 24
Nov. 30, 1881 ..	4	50	227	214	39	534

The Royal Society. Balance Sheet, 1881.

Statement of Receipts and Expenditure from November 26, 1880, *to November* 24, 1881.

Receipts		£	s.	d.
Annual Contributions, 221 at £4	£884	1,001	0	0
" 39 at £3	117			
Admission Fees		30	0	0
Fee Reduction Fund, in lieu of Admission Fees and Annual Contributions		189	0	0
Compositions		120	0	0
Rents		254	9	2
Dividends (exclusive of Trust Funds)		1,134	5	2
" on Jodrell Fund		151	18	4
Interest on Mortgage Loan		585	17	6
Sale of Transactions and Proceedings		931	6	8
Donation from Miss Pipe towards the cost of Plates for Prof. Parker's Papers		105	0	0
Sale of land at Acton		450	0	0
Petty Repayments		3	3	10
Interest on purchase-money for Sale of Land at Acton		567	3	8
Sale of £666 13*s*. 4*d*. Consols		666	13	4
		£6,189	17	8

Expenditure	£	s.	d.	£	s.	d.
Salaries and Wages				1,083	13	0
The Library Catalogue				181	15	3
Books for the Library				214	9	1
Printing Transactions, Parts II. and III. 1880, Parts I. and II. 1881, and Separate Copies to Authors and Publisher	625	15	5	2,228	6	8
Ditto Proceedings, Nos. 207–214	377	12	7			
Ditto Miscellaneous	58	14	11			
Paper for Transactions and Proceedings	290	8	0			
Binding ditto	192	5	11			
Engraving and Lithography	683	9	10			
Soirée and Reception Expenses				80	13	1
Coal, Lighting, &c.	88	18	2	365	1	9
Office Expenses	23	9	11			
House Expenses	77	17	7			
Tea Expenses	18	9	11			
Fire Insurance	41	15	0			
Taxes	39	2	6			
Advertising	18	9	0			
Postage, Parcels, and Petty Charges	38	4	2			
Miscellaneous Expenses	18	15	6			
Law Charges				190	6	8
Purchase of £600 Midland Railway 4 % Debentures				678	10	0
" £525 14*s*. 0*d*. Consols				522	8	4
				£5,545	3	10

Trust Funds.

	£	s.	d.	£	s.	d.
Donation Fund Dividends	417	3	7			
Portion of Borneo Cave Exploration expenses returned	45	6	6			
Rumford Fund Dividends	67	19	0			
Wintringham Fund ,,	35	2	0	635	0	11
Copley Medel Fund ,,	34	6	3			
Davy Medal Fund ,,	32	4	10			
Croonian Lecture Fund—Rent from College of Physicians	2	18	9			
Balance at Bank, Dec., 1880	1,178	9	7	1,195	5	1
Do. on hand	16	15	6			
				£8,020	3	8

	£	s.	d.	£	s.	d.
Rumford Medal Fund	136	9	4			
Davy Medal Fund	32	11	0			
Wintringham Fund	35	5	0	215	15	3
Copley Medal Fund	4	11	2			
Bakerian Lecture	4	0	0			
Croonian Lecture	2	18	9			
Balance at Bank				2,241	11	8
Balances on hand, Catalogue Account	11	14	3	17	12	11
,, ,, Petty Cash	5	18	8			
				£8,020	3	8

JOHN EVANS,
Treasurer.

Estates and Property of the Royal Society, including Trust Funds.

Estate at Mablethorpe, Lincolnshire (55 A. 2 R. 2 P.), £110 per annum.
Estate at Acton, Middlesex (about 33 acres), £152 per annum (Contract for Sale sealed).
Fee Farm near Lewes, Sussex, rent £19 4*s*. per annum.
One-fifth of the clear rent of an estate at Lambeth Hill, from the College of Physicians, £3 per annum.
Stevenson Bequest. Chancery Dividend. One-fourth annual interest on £85,336, Government Annuities and Bank Stock (produced £482 18*s*. 9*d*. in 1880–81).

£21,000 { £14,952 12*s*. 3*d*. Reduced 3 per Cent. Annuities.
£6,047 7*s*. 9*d*. " " " Handley Fund. }

£15,000 Mortgage Loan, 4 per Cent.

£18,314 0*s*. 2*d*. Consolidated Bank Annuities, { being £14,861 19*s*. 1*d*. in name of the R. S., and £3,452 1*s*. 1*d*. in Chancery, arising from sale of the Coleman Street Estate. }

£200 " " —The Gassiot Trust.
£403 9*s*. 8*d*. New 2½ per Cent. Stock—Bakerian and Copley Medal Fund.

£11,511 6*s*. New Threes { £6,328 11*s*. 2*d*. Scientific Relief Fund.
5,182 14*s*. 10*d*. Jodrell Fund. }

£667 5*s*. 6*d*. India Fours.
£660 Madras Guaranteed 5 per Cent. Railway Stock.—Davy Medal Fund.
£10,000 Italian Irrigation Bonds.—The Gassiot Trust.
£1,396 Great Northern Railway 4 per Cent. Debentures—The Trevelyan Bequest.
£100 Metropolitan 3½ per Cent. Stock.—Scientific Relief Fund.
£1,550 " " —Fee Reduction Fund.
£7,000 London and North Western Railway 4 per Cent. Debentures. } " "
Two Hundred Shares in the Whitworth Land Company, Limited. } " "

We, the Auditors of the Treasurer's Accounts on the part of the Council, have examined these Accounts and found them correct; and we find that the Balance at the Bankers' is £2,241 11*s*. 8*d*.

W. SPOTTISWOODE, *Pres.*
G. G. STOKES, *Sec.*
T. G. BONNEY.
A. J. ELLIS.
H. T. STAINTON.

We, the Auditors of the Treasurer's Accounts on the part of the Society, have examined these Accounts and found them correct; and we find that the Balance at the Bankers' is £2,241 11*s*. 8*d*.

W. G. ADAMS.
J. T. BOILEAU.
H. CLERK.
P. M. DUNCAN.
R. H. SCOTT.

Trust Funds. 1881.

Scientific Relief Fund.

	£	s.	d.
New 3 ger Cent. Annuities	6,328	11	2
Metropolitan 3½ Consols	100	0	0
	£6,428	11	2

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Balance	100	1	8	By Grants	205	0	0
,, Dividends and Donation	190	0	7	,, Balance	85	2	3
	£290	2	3		£290	2	3

Donation Fund.

£6,339 0*s.* 1*d.* Consols.
The Trevelyan Bequest.
£1,396 Great Northern Railway 4 per Cent. Debentures.

	£	s.	d.		£	s.	d.
To Balance	330	2	0	By Balance	792	12	1
,, Dividends, and Balance repaid	285	4	10				
,, Transferred from Handley Fund	177	5	3				
	£792	12	1		£792	12	1

Rumford Fund.

£2,322 19*s.* Consols.

	£	s.	d.		£	s.	d.
To Balance, 1880	136	9	4	By Medals	59	12	0
,, Dividends, 1881	67	19	0	,, W. Huggins	76	17	4
				,, Balance	67	19	0
	£204	8	4		£204	8	4

Bakerian and Copley Medal Fund.

Sir Joseph Copley's Gift, £1,666 13*s.* 4*d.* Consols.
£403 9*s.* 8*d.* New $2\frac{1}{2}$ per Cent.

	£	s.	d.		£	s.	d.
To Balance	76	9	0	By Gold Medal	4	11	2
,, Dividends	9	16	8	,, Bakerian Lecture	4	0	0
,, Dividend—Sir J. Copley's Fund	24	9	7	,, Balance	102	4	1
	£110	15	3		£110	15	3

The Keck Bequest.

£600 Midland Railway 4 per Cent. Debenture Stock.

	£	s.	d.		£	s.	d.
To Dividend, July, 1831	11	15	0	By Balance	11	15	0

Wintringham Fund.

£1,200 Consols.

	£	s.	d.		£	s.	d.
To Balance, 1880	35	5	0	By Payment to Foundling Hospital, 1881	35	5	0
,, Dividends, 1881	35	2	0	,, Balance	35	2	0
	£70	7	0		£70	7	0

Croonian Lecture Fund.

	£	s.	d.		£	s.	d.
To Balance, 1880	2	18	9	By Croonian Lecture	2	18	9
,, One-fifth of Rent of Estate at Lambeth Hill, payable by the College of Physicians	2	18	9	,, Balance	2	18	9
	£5	17	6		£5	17	6

Davy Medal Fund.

£660 Madras Guaranteed 5 per Cent. Railway Stock.

	£	s.	d.		£	s.	d.
To Balance	139	5	0	By Gold Medal	32	11	0
,, Dividends	32	4	10	,, Balance	138	18	10
	£171	9	10		£171	9	10

The Gassiot Trust.

£10,000 Italian Irrigation Bonds.
£200 3 per Cent. Consols.

	£	s.	d.		£	s.	d.
To Balance	130	18	6	By 2 Italian Bonds bought	214	5	0
,, Dividends	502	10	11	,, Payments to Kew Committee	496	13	8
,, Bonds drawn	234	10	0	,, Balance	157	0	9
	£867	19	5		£867	19	5

Handley Fund.

£6,047 7*s.* 9*d.* Reduced.

	£	s.	d.		£	s.	d.
Dividends, 1881	177	5	3	By transferred to Donation Fund	177	5	3

The Jodrell Fund.

£5,182 14*s.* 10*d.* New 3 per Cent. Stock.

	£	s.	d.		£	s.	d.
To Dividends, 1881	151	18	4	By transferred to Royal Society General Account	151	18	4

Fee Reduction Fund.

£1,550 Metropolitan Consols $3\frac{1}{2}$ per Cent
£7,000 London and North Western Railway 4 per Cent. Debentures.
Two Hundred Shares in the Whitworth Land Company, Limited.

	£	s.	d.		£	s.	d.
To Balance (1880)	88	13	1	By Transferred to Royal Society General Account (1881)	189	0	0
,, Dividends	412	14	0	,, Purchase of £250 Metropolitan Consols $3\frac{1}{2}$ per Cent.	263	8	9
				,, Balance	48	18	4
	£501	7	1		£501	7	1

Account of the appropriation of the sum of £1,000 (the Government Grant) annually voted by Parliament to the Royal Society, to be employed in aiding the Advancement of Science (continued from Vol. XXXI, p. 110.)

1881.

	£	s.	d.
Professor Cayley, for Apparatus for the Kinematical Construction of Functions of a Complex Variable $x + iy$ ..	50	0	0
R. H. M. Bosanquet, for Balance of the cost of an Engine with Clock, Bellows, and other Appliances to be employed in the Solution of various Problems in Acoustics ..	99	5	3
Professor W. G. Adams, for the Expense of procuring Photographs of Magnetic Tracings from various Observatories over the Globe, and for assistance in comparing and examining them, so as to arrive at a more exact knowledge of the Laws of Terrestrial Magnetism	200	0	0
A. Mallock, for completing the construction of the Room for the Diffraction Grating Ruling Machine	30	0	0
Rev. A. E. Eaton, to defray further the cost of Printing and Publishing a descriptive Monograph of the Ephemeridæ	120	0	0
G. E. Dobson, for an Examination of the Anatomical Structure, Systematic Position, and Geographical Distribution of the Species of the Order Insectivora, to be published in the form of a Monograph, illustrated with plates from original drawings by the Author	100	0	0
D. J. Hamilton, for a Research into the Topographical Anatomy of the Central Nervous System studied in relation to its Physiology	50	0	0
A. Frazer, for Apparatus for a Series of Experiments on Wind Pressure. (1) Rate of variation of pressure on different sized plates. (2) Pressure on perforated plates, and wire gauze disks. (3) Lifting power of air currents	25	0	0
	£674	5	3

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Balance on hand, Nov. 30, 1880.....................	1,117	18	2	By Appropriations, as above............	674	5	3
Grant from Treasury, 1881	1,000	0	0	Printing, Postage, and Advertising	8	14	0
Repayment.................	11	7	4	Balance on hand, Nov. 30, 1881	1,446	6	3
	£2,129	5	6		£2,129	5	6

Account of Appropriations from the Government Fund of £4,000 made by the Lords of the Committee of Council on Education, on the recommendation of the Council of the Royal Society.

1880–81.

G. F. Rodwell, for continuation of his Experiments on the Anomalous Coefficients of Expansion of certain Iodides, Chlorides, and Bromides	£30
A. Macfarlane, for extending his Researches into the Disruptive Discharge of Electricity	50
Professors Liveing and Dewar, for apparatus and materials required in continuing their Spectroscopic Investigations	200
J. N. Lockyer, for continuation of Researches on the Solar Spectrum	150
R. S. Marsden, for development of a new Theory for the Hardening of Steel, with special reference to the State of Carbon in Steel	15
J. Parry and A. E. Tucker, for aid in continuing Experiments on the application of the Spectroscope to the Analysis of Iron and Steel	100
A. Tribe, for continuation of Researches into Electric Distribution as manifested by that of the Radicles of Electrolytes	75
W. Crookes, for assistance in continuing Researches in Molecular Physics in High Vacua	200
Dr. T. Carnelley, for a Research on the Action of Heat on Substances under diminished Pressure, and the existence of Ice and other Bodies at Temperatures above their ordinary Melting Points	100
Professor W. N. Hartley, for payment of an Assistant, and the cost of Materials and Apparatus employed in his Investigations of the Ultra-violet Rays of the Spectrum	100
Professor O. J. Lodge, in aid of Researches, more especially into the Action of Light on the Conductivity and Residual Charge Phenomena of Glass and Electrolytes	100
Professor R. Grant, for the Expense of Printing a Catalogue of the Mean Places of 6,350 Stars, based on Observations made at the Glasgow Observatory	300
J. Glaisher, towards the Expense of Printing the Factor Table of the Sixth Million	150
R. McLachlan, in aid for continuation of his Researches on European Trichopterous Insects	25
Carried forward	£1,595

Brought forward................	£1,595
Professor Duncan and P. Sladen, for the cost of an Additional Plate (*Comatulæ*) in their Monograph on Arctic Echinodermata	10
Professor Heddle, for continuation of a Research connected with the Scientific Mineralogy and Geognosy of Scotland: £100 for Analyses, and £100 for personal expenses in collecting Specimens..	200
E. C. Rye, in aid of the Publication Fund of the Zoological Record Association	100
Dr. R. Braithwaite, for aid in publishing a work on the British Moss Flora	50
D. Mackintosh, for continuation of his Search for High Level Gravel and Sand with Marine Shells along the Northern and Eastern Slopes of the Welsh Mountains, and along the Western Slopes of the Pennine Hills	20
Professor Nicholson and R. Etheridge, jun., for Further Assistance towards the Publication of the Third Fasciculus of their "Monograph of the Silurian Fossils of Girvan, Ayrshire"	100
J. N. Langley, for an Investigation into the changes which take place in the Gland Cells of the Liver and Kidney during Secretion	30
J. S. Gardner, for assistance in working out more systematically than has yet been done, the Mull, Antrim and Iceland Tertiary Plant Beds	150
Professor W. T. Dyer, for aid in the preparation of an illustrated Monograph of Cycadæa	20
E. A. Schäfer, for payment of an Assistant in continuing his Histological and Embryological Investigations	50
Dr. G. Thin, for investigation of the Epithelium, and of the Lens and Retina in the Tadpole, and the Influence of Light on the Development of the Tadpole	25
Rev. J. F. Blake, for aid in preparing and publishing a work on British Fossil Cephalopoda	100
Dr. F. R. Japp, for an Investigation of the Reactions and Decompositions of the Quinones; with a view to throw light on the constitution of this Group of Compounds, and indirectly upon that of the Benzene Series generally	50
C. F. Cross, for materials to be used in the Extension of his Research into the Rehydration of Metallic Oxides	10
J. H. Collins, for continuation of Chemical, Mineralogical, Microscopical, and Stratigraphic Observations on, and Investigations of the Rocks of Cornwall	30
Dr. C. R. A. Wright, for continuation of Researches on the	
Carried forward................	£2,540

Brought forward................	£2,540
Determination of Chemical Affinity in Terms of Electromotive Force	200
C. E. Groves for Researches into Lichen Products and Derivatives obtained from Naphthalene now in progress, originally undertaken in conjunction with the late Dr. Stenhouse........	200
R. Etheridge, jun., and P. H. Carpenter, for the Preparation of a Monograph of the Blastoidea, especially of British Species, with their Morphology	60
Dr. Fraser, for a Research on the Action of Medicines on the Heart and Peripheral Circulation	30
E. Neison, for continuation of Computations in the Lunar Theory	75
Dr. G. Gore, for Investigation of the Phenomena of Electric Osmose, the production of Electric Currents by Liquid Diffusion, and (probably) the Transmission of Electric Currents by Liquids	100
H. Tomlinson, for his Researches on the Influence of Stress and Strain on the Action of Physical Forces	100
Rev. J. Henslow, for Physiological Researches on the Transpiration of Plants, the effect of Coloured Light thereon, and to discover the different nature of Coloured Leaves by means of the Spectroscope	50
W. K. Parker, for assistance in his Researches into the Morphology of the Vertebrata	300
F. O. Bower, for a Research into the Minute Histology of Plants, more especially of *Welwitschia mirabilis*	100
W. Saville Kent, for the further prosecution of Investigations into the Structure and Life History of certain Lower Protozoa..	100
C. Lapworth, for Investigation of the Lower Palæozoic Rocks of Scotland, and of the Family of the Graptolites	80
Spencer U. Pickering, for a Research into Molecular Combinations..	50
	£3,985
Administrative Expenses	15
	£4,000

Report of the Kew Committee for the Year ending October 31, 1881.

The operations of the Kew Observatory, in the Old Deer Park, Richmond, Surrey, are controlled by the Kew Committee, which is constituted as follows:

General Sir E. Sabine, K.C.B., *Chairman*.

Mr. De La Rue, *Vice-Chairman*.
Capt. W. de W. Abney, R.E.
Prof. W. G. Adams.
Capt. Sir F. Evans, K.C.B.
Prof. G. C. Foster.
Mr. F. Galton.
Vice-Adm. Sir G. H. Richards, C.B.
The Earl of Rosse.
Mr. R. H. Scott.
Lieut.-General W. J. Smythe.
Lieut.-Gen. R. Strachey, C.S.I.
Mr. E. Walker.

Lieut.-Gen. Sir J. H. Lefroy, K.C.M.G., having been appointed Deputy-Governor of Tasmania, withdrew from the Committee in December, and Capt. Abney was elected to fill the vacancy.

The work at the Observatory may be considered under seven heads:—

1st. Magnetic observations.
2nd. Meteorological observations.
3rd. Solar observations.
4th. Experimental, in connexion with any of the above departments.
5th. Verification of instruments.
6th. Aid to other Observatories.
7th. Miscellaneous.

I. Magnetic Observations.

On January 10 the magnetograph needles were dismounted and re-magnetized, having become weakened by age. Since then work has continued as usual.

The scale values of all the instruments were re-determined in January, in accordance with the practice of previous years, both before and after the re-magnetization of the needles.

The following are the values of the ordinates of the various photographic curves:—

Declination		1 inch	= 0° 22′·04.	1 mm. = 0° 0′·87.
Bifilar Jan. 4, 1881,	for	1 inch	dH=0·0739 foot grain units.	
	,,	1 mm.	,, =0·00134 mm. mgr. units.	
,, Jan. 12, 1881	,,	1 inch	,, =0·0442 foot grain units.	
	,	1 mm.	,, =0·00080 mm. mgr. units.	
Balance Jan. 7, 1881	,,	1 inch	dV=0·0643 foot grain units.	
	,,	1 mm.	,, =0·00117 mm. mgr. units.	
,, Jan. 14, 1881	,,	1 inch	,, =0·0323 foot grain units.	
	,,	1 mm.	,, =0·00059 mm. mgr. units.	

Two magnetic storms, or periods of considerable disturbance of the needles, have been registered during the year; one on the night of January 31st, and a second on September 12th and 13th, both being accompanied by brilliant auroral displays.

The monthly observations with the absolute instruments have been made regularly, and the results are given in the tables forming Appendix I of this Report.

Professor W. Grylls Adams has during the year continued his investigations on the comparison of magnetic disturbances in various localities. In addition to the curves mentioned in last year's Report, he has received through the Committee several supplies of copies of selected traces from Mauritius, Toronto, and Zi-Ka-Wei, near Shanghai, as well as from those Observatories already enumerated in the last report.

Professor Adams has embodied the results of his researches in two papers read before the British Association, and in a Friday evening lecture delivered at the Royal Institution.

The discussion of the great magnetic storm of January 31st, 1881, having been undertaken by Dr. H. Wild, of the Central Physical Observatory, St. Petersburg, such particulars respecting that occurrence as the Committee possessed were transmitted to that gentleman.

The magnetic instruments have been studied, and a knowledge of their manipulation obtained by Lieutenant Moore, R.N., Dr. Brauner, and Dr. Monckman.

Information on matters relating to terrestrial magnetism and various data have been supplied to Professor W. G. Adams, Dr. Atkinson, Dr. Buys Ballot, Mr. Gee, Mr. J. E. H. Gordon, Rev. F. Howlett, M. Mascart, Dr. Müller, Professor Balfour Stewart, and Dr. Wild.

The following is a summary of the number of magnetic observations made during the year:—

Determinations of	Horizontal Intensity........	29
,,	Dip	160
,,	Absolute Declination	43

II. Meteorological Observations.

The several self-recording instruments for the continuous registration respectively of, atmospheric pressure, temperature, and humidity, of wind (direction and velocity), sunshine, and rain have been maintained in regular operation throughout the year.

The standard eye observations made five times daily, for the control of the automatic records, have been duly registered through the year, together with the additional daily observation at 0 h. 8 m. P.M. in connexion with the Washington synchronous system. The 6 h. 45 m. P.M. observation, for the second synchronous system organized by M. Mascart, Directeur du Bureau Central Météorologique, Paris, was discontinued on December 31st.

The tabulation of the meteorological traces has been regularly carried on, and copies of these, as well as of the eye observations, with notes of weather, cloud, and sunshine have been transmitted weekly to the Meteorological Office.

The following is a summary of the number of meteorological observations made during the past year:—

Readings of standard barometer	1929
" dry and wet thermometers	7508
" maximum and minimum thermometers	2190
" radiation thermometers	750
" rain gauges	730
Cloud and weather observations	2294
Measurements of barograph curves	9125
" dry bulb thermograph curves	9125
" wet bulb thermograph curves	8986
" wind (direction and velocity)	17320
" rainfall curves	717
" sunshine traces	2149

In compliance with a request made by the Meteorological Council to the Kew Committee, the Observatories at Aberdeen, Armagh, Falmouth, Glasgow, Oxford (Radcliffe), Stonyhurst, and Valencia, have been visited as on former occasions, and their instruments inspected by Mr. Whipple during his vacation.

With the concurrence of the Meteorological Council, weekly abstracts of the meteorological results have been regularly forwarded to, and published by "The Times," "The Illustrated London News," and "The Torquay Directory," and meteorological data have been supplied to the editor of "Symons's Monthly Meteorological Magazine," the Secretary of the Institute of Mining Engineers, Messrs. Buchan, Eaton, Greaves, Gwilliam, McDonald, Rowland, and others.

Electrograph.—This instrument has been in continuous action through the year, with the exception of a few occasions during the severe frost of last winter.

In July the instrument was dismounted, and a fresh supply of acid placed in the jar, the charge-keeping properties of which had become slightly deteriorated.

The tabulation of the curves given by this instrument has at last been commenced, and a suitable glass scale, arranged on a plan devised by Mr. Whipple, having been constructed by Mr. Baker, the average hourly tension of atmospheric electricity at the collector of the Electrograph has been determined for every hour in 1880, except in those cases where registration failed either from disturbance or instrumental defect.

From these values the daily, monthly, and annual means have been deduced, together with other facts bearing on the relations existing between atmospheric electricity and different meteorological phenomena. Some results of this investigation were by permission of the Meteorological Council submitted by the Superintendent to the Meeting of the British Association at York, in a paper which has since been ordered by the General Committee to be printed *in extenso* among their Reports. The expense of the tabulation was defrayed by a special grant from the Meteorological Council.

III. Solar Observations.

The only solar work done at Kew during the past year has been the regular maintenance of the eye observations of the sun, after the method of Hofrath Schwabe, as described in the Report for 1872. These have been made on 187 days, in order to preserve the continuity of the Kew records of sun-spots. The sun's surface was observed to be free from spots on three of those days.

A small portable $2\frac{3}{4}$ in. refracting telescope, with a magnifying power of 42 diameters, is used by the observer.

Transit Observations.—Ninety-four observations have been made of sun-transits, for the purpose of obtaining correct local time at the Observatory: 126 clock and chronometer comparisons have also been made.

In addition to these a considerable number of star transits have been observed in connexion with the pendulum operations in progress during the autumn of 1881.

IV. Experimental Work.

Winstanley's Recording Radiograph.—This instrument, designed for the purpose of registering continuously the amount of radiation from the sky, by mechanical means, upon a sheet of blackened paper, still remains at the Observatory, but having been accidentally deranged, it has not been at work for some months. The inventor being abroad it has not been possible to place it in re-adjustment.

Nephoscopes.—Experiments have been made with several forms of nephoscope designed by Mr. F. Galton, and also with a new cloud-camera, designed by the Superintendent.

Exposure of Thermometers.—Experiments have been continued throughout the year at the Observatory, with the view of determining the relative merits of different patterns of thermometer screens. For this purpose there were erected in 1879 on the lawn a Stevenson's screen, of the ordinary pattern, and a large wooden cage, containing a Wild's screen, of the pattern employed in Russia. Each of these screens contains a dry and a wet bulb thermometer, and a maximum and minimum, all of which are read daily at 9 A.M. and 9 P.M., their indications being compared with those of the thermograph at the same hours. A third portable metal screen, designed by Mr. De La Rue for use on board Light-ships, which contains a dry bulb thermometer only, is also carried into the open air by the observer, and read at the same time as the fixed instruments.

The cost of these experiments is borne by the Meteorological Council.

Glycerine Barometer.—This instrument, devised and erected by Mr. Jordan, has remained in successful operation throughout the year. In compliance with the request of the inventor, it has been continuously observed five times daily, in conjunction with the mercurial barometer.

Mr. Jordan has been supplied with copies of the observations, but the Committee have not yet, however, been informed of the results of these comparisons.

Pendulum Experiments.—In March, the Committee received a communication from the Council of the Royal Society, calling their attention to the fact that the invariable pendulums deposited in the Loan Collection of scientific instruments at South Kensington, could not be considered as in the custody of the Committee, and in consequence the Science and Art Department was requested to return the instruments to the Observatory. They were accordingly received on the 15th of June.

Subsequently an application was received from Major Herschel, R.E., F.R.S., by authority of the India Office, for permission to make certain experiments with the pendulums, and for the loan of the instruments, with their accompanying appliances, with facilities for prosecuting the experiments at the Observatory.

These requests were granted, and since the beginning of September operations have been continuously carried on, both in the Pendulum Room and in the Experimental House at Kew.

The Indian Government will defray all expenses that may be incurred in the prosecution of the experiments.

V. Verification of Instruments.

The following magnetic instruments have been verified, and their constants have been determined :—

A set of Self-recording Magnetographs for the Nice Observatory.
A Unifilar Magnetometer for Casella.
Three Dip Circles for Casella.
A pair of Dipping Needles for Elliott Brothers.

There have also been purchased on commission and verified :—

A Unifilar Magnetometer and Dip Circle for Professor Tacchini, Rome.
A Unifilar Magnetometer and Dip Circle for Professor Perard, Liége.
A Dip Circle for Capt. Hoffmeyer, Copenhagen.
A Dip Circle for Professor Malmberg, Stockholm.
A Pair of Dipping Needles for the Colaba Observatory.
A Dip Needle for Senhor Capello, Lisbon.

The number of meteorological instruments verified continues still to increase, having been in the past year as follows :—

Barometers, Standard	59
,, Marine and Station	109
Aneroids	34
Total	202

Thermometers, ordinary Meteorological	1704
,, Standard	60
,, Mountain	40
,, Clinical	4217
,, Solar radiation	64
Total	6085

Besides these, 36 Deep-sea Thermometers have been tested, 17 of which were subjected in the hydraulic press, without injury, to pressures exceeding three and a half tons on the square inch, and 18 Thermometers have been compared at the freezing-point of mercury, making a total of 6139 for the year.

Duplicate copies of corrections have been supplied in 20 cases.

Ten Standard Thermometers have also been calibrated and divided, and supplied to societies and individuals during the year.

The following miscellaneous instruments have also been verified :—

Hydrometers	47
Anemometers	3
Rain Gauges	6
Theodolites	3
Sextants	25
Index Glasses for ditto, unmounted	23
Horizon ,, ,, ,,	26
Coloured Shades ,, ,,	188

There are at present in the Observatory undergoing verification, 8 Barometers, 395 Thermometers, and 7 Hydrometers.

A considerable increase having taken place in the number of Sextants submitted for verification, the Committee, after due consideration, have withdrawn the old form of certificate of examination, and substituted a more general statement of the efficiency of the instrument, recognising in future two classes of sextant; Class A in which the total error of the instrument, from any cause, nowhere exceeds thirty seconds; and Class B where the limit is a maximum error of three minutes of arc.

The schedule of fees payable for the verification of instruments has been revised, and copies of the new scale, together with particulars as to the transmission, &c., of instruments to and from the Observatory for the purpose of comparison, have been widely distributed amongst opticians and instrument makers.

Standard Barometers.—From time to time comparisons have been made between the two Welsh Standard Barometers, the old Royal Society Standard, and Newman No. 34, the working Standard of the Observatory. The Portable Standards of the Observatory have also been employed in making comparisons of the Standard Barometers at the Hydrographic Office, Admiralty, the University Museum, Oxford, and the Royal Engineering College, Cooper's Hill.

A metal plate, engraved with an inscription stating the history of the old Royal Society Standard Barometer, and giving details of the method employed in filling it on the occasion of its recent repair, has now been affixed to the instrument.

The large difference formerly observed in the heights of the mercurial column in the flint and crown glass tubes of this barometer, has not been found to exist in the refilled tubes, and the mean difference between their indications is now less than 0·001 inch.

Standard Thermometers.—The Committee has exchanged Standard Thermometers with the Johns Hopkins University, U.S.A., Professor Rowland having on the occasion of his recent visit to this country presented the Observatory with a Standard—Baudin 7835—which he has compared very closely with his other standard instruments.

The Committee has received very gratifying testimony as to the accuracy of the Standard Thermometers constructed at the Observatory. In a paper contributed to the "American Journal of Science," Dr. Leonard Waldo, of the Winchester Observatory, Yale College, U.S.A., remarks that after a critical examination of three Kew Standard Thermometers, in which every degree was separately measured, entailing no less than 2,300 micrometer readings, he came to the conclusion that their errors are practically insensible and too small to be detected with certainty.

Professors Thorpe and Rücker have also been engaged in testing very minutely three similar instruments made for them at Kew. In a paper read at York before the British Association, Professor Rücker stated "they had subjected the Kew Thermometers to the most rigorous test possible, and they were able to announce that in one instrument the errors left, after the application of Welsh's method of calibration and graduation, were not greater than four thousandths of a degree Centigrade, and in no case did they much exceed one-hundredth of a degree. As it is impossible to read on these thermometers less than a hundredth of a degree with certainty, Welsh's method as applied at Kew is almost perfect."

VI. Aid to Observatories.

Waxed Papers, &c., supplied.—Waxed paper has been supplied to the following Observatories:—

Aberdeen, Adelaide, Armagh, Bengal (Meteorological Department), Colaba, Falmouth, Glasgow, Mauritius, Paris (Montsouris), Oxford (Radcliffe), Utrecht, Stonyhurst, St. Petersburgh.

Anemograph Sheets have been sent to the Mauritius Observatory, and

Blank Magnetic Observation Forms have been supplied to

Professor Reinold, Royal Naval College;

Professor Louis Perard, l'Universite de Liége;

Professor Poynting, Mason's Science College, Birmingham;

and to Mr. Casella.

VII. Miscellaneous.

Loan Exhibition.—The instruments specified in the Report for 1876 still remain in charge of the Science and Art Department, South Kensington, with the exception of the Invariable Pendulum Apparatus recently withdrawn, as already stated, and the few articles mentioned in previous reports.

Fog Prevalence.—At the request of the Meteorological Council the

Meteorological Registers of the Observatory were searched from 1843 to the end of 1880, and an enumeration made of all the observations of fog and mist recorded in them. The cost of the examination was defrayed by the Council.

Lost Journals.—On going through the books of the Observatory for the purpose of compiling the above-mentioned tables, it was found that the volumes containing observations made between January and June 1845, and August 1848, and December 1853, were missing. On making inquiry it was discovered that the volumes containing the MSS. results for 1845 and 1849 to 1851 were in the library bequeathed by the late Sir F. Ronalds to the Society of Telegraph Engineers and Electricians, and the Council of that Society most courteously directed these records to be restored to the custody of the Kew Committee, which has been done.

Further search has failed to bring to light any regular records of observations made between April 1851, and January 1854; and it is believed that none were made during the interval which elapsed between the discontinuance of the system of observations organised under the superintendence of Sir F. Ronalds and that established by Mr. J. Welsh, after his own appointment as Superintendent.

Complete specimen sets of curves from the various photographic and autographic instruments in use at the Observatory have been prepared and forwarded to the exhibitions of the

Leeds Philosophical and Literary Society,
Yorkshire Fine Art and Industrial Institution,
Richmond Industrial and Fine Art Loan Exhibition, and the
International Photographic Exhibition at Vienna.

At the latter exhibition a silver medal was awarded to the Committee for their exhibit.

The Superintendent has, with the consent of the Committee, read the following papers before the Meteorological Society, all of which have been published in the "Quarterly Journal" of the Society:—

1. "On the Variations of Relative Humidity and Thermometric Dryness of the Air, with Changes of Barometric Pressure at the Kew Observatory," vol. vii, p. 49.

2. "On the Relative Frequency of given Heights of the Barometer Readings at the Kew Observatory during the ten years 1870–79," vol. vii, p. 52.

3. "Results of Experiments made at the Kew Observatory with Bogen's and George's Barometers," vol. vii, p. 185.

4. "Note on a Discussion of Mr. Eaton's Table of Barometric Height at London, with regard to Periodicity," vol. vii, p. 189.

Workshop.—The several pieces of Mechanical Apparatus, such as the Whitworth Lathe and Planing Machine, procured by Grants from either the Government Grant Funds or the Donation Fund, for the use of the Kew Observatory, have been kept in thorough order, and many of them are in constant, and others in occasional, use at the Observatory, but the funds of the Committee do not allow of the employment of a mechanical assistant, although one is much needed.

Library.—During the year the Library has received, as presents, the publications of

13 English Scientific Societies and Institutions, and

72 Foreign and Colonial Scientific Societies and Institutions.

Ventilation Experiments.—The experiments on the ventilating power of cowls of different form by the Sub-Committee of the Sanitary Institute of Great Britain are still in progress in the wooden hut erected by the Institute near the Observatory, the experimental house lent by the Committee having been required for the testing of Magnetographs and other purposes.

Observatory and Grounds.—The buildings and grounds have been kept in repair throughout the year, and the exterior woodwork has been painted by the Board of Works.

The basement of the building having been again flooded, a drain has been laid across the park to the riverside to allow of flood-waters flowing directly into the river instead of requiring to be pumped out as has hitherto been necessary.

The roofs of the Verification House and Magnetic Observatory have been entirely re-covered with felt, and new gutters fitted, &c.

No action having been taken by the Commissioners of Woods and Forests with respect to the footpath across the park, its *temporary* repair has, however, been carried on at the expense of the Committee.

Personal Establishment.

The staff employed is as follows:—

G. M. Whipple, B.Sc., Superintendent.
T. W. Baker, First Assistant.
J. Foster, Verification Department.
H. McLaughlin, Librarian and Accountant.
F. G. Figg, Magnetic Observer.
E. G. Constable, Solar Observations and Tabulation of Meteorological Curves.
T. Gunter } Verification Department.
C. Taylor }
W. Boxall, Photography.
E. Dagwell, Office duties.
J. Dawson, Messenger and Care-taker.

J. W. Hawkesworth, H. Clements, and A. Dawson have resigned their appointments during the year.

In consequence of a case of illness of a contagious nature having occurred in the care-taker's family, work was almost suspended in the Observatory for some days in May, but the self-registering instruments were maintained in action, so that no loss of records took place during the time.

Visitors.—The Observatory has been honoured by the presence during the year of numerous visitors, many of whom were foreigners.

Abstract. *Kew Observatory Receipts and Payments Account from November 3, 1880, to November 2, 1881.*

Dr. RECEIPTS.

	£ s. d.	£ s. d.
To Balance from 1879–80		375 19 11
Royal Society (Gassiot Trust)	£247 16 3	
,, ,,	248 17 5	
		496 13 8
Meteorological Office		400 0 0
Meteorological Office, for Postages, &c.		44 17 2
Payment for Instruments on Commission		153 2 4
Sale of Waxed Paper		121 15 6
Verification Fees, Meteorological Office	95 7 0	
,, ,, Observatories and Institutions	32 16 2	
,, ,, Opticians, &c.	395 5 3	
Sale of Standard Thermometers	19 16 6	
Payments for Copying Registers	52 15 0	
		595 19 11
Sanitary Institute of Great Britain for Experimental Work		10 17 1
Mr. De La Rue for Sun-work		8 6 8
Sale of Photographic Residues		6 12 0
		£2214 4 3

PAYMENTS. *Cr.*

	£ s. d.	£ s. d.
By Salaries	£998 2 10	
Extra Payments	72 17 1	
		1070 19 11
Rent of Enclosure	11 11 0	
Fuel and Gas	51 2 5	
Furniture and Fittings	40 14 6	
Chandlery, &c.	9 2 3	
Painting and Repairs	12 6 2	
Maintenance of Path and Fence	6 12 9	
Expenses on account of Illness	20 0 0	
		151 9 1
Printing and Stationery	37 5 5	
Postages	16 9 4	
Library	10 10 5	
Messenger and Housekeeper	62 8 0	
Advertisements	4 11 6	
Porterage and Contingencies	15 11 9	
		145 16 5
Instruments purchased on Commission		204 17 6
Postages and Payments on behalf of Meteorological Office		47 7 7
Purchase of Waxed Paper, Packing ditto, &c.		87 13 4
,, ,, Chemicals and Materials	28 8 0	
,, ,, Tubes for Standard Thermometers	2 4 8	
Verification Department Expenses (Ice, Carbonic-Acid Gas, &c.)	10 15 0	
Repair of Instruments, and Purchase of New	35 12 10	
Carpenter's Work and Sundries	2 19 6	
		80 0 0
Payments on behalf of Experimental Work		2 12 1
,, ,, Sun-work		8 6 8
Balance—Bank of England	324 4 0	
London and County Bank	75 0 0	
Cash in hand	14 7 8	
		414 1 8
		£2214 4 3

November 10, 1881. Examined and compared with the Vouchers, and found correct. (Signed) G. CAREY FOSTER, *Auditor.*

ASSETS.

	£ s. d.
By Balance as per Statement	414 1 8
Meteorological Office, Allowances and Sundries	39 8 8
Commissions	106 1 0
Waxed Paper in stock	24 0 0
,, ,, sold	11 5 0
Blank Forms	1 13 9
Verification Fees due	87 13 9
Standard Thermometers sold	4 7 0
,, ,, in stock	90 0 0
	£778 10 10

LIABILITIES.

	£ s. d.
To Gas, Fuel, and House Account	1 15 4
Apparatus, Chemicals, &c.	6 17 0
Commissions	36 19 8
Stationery and Printing	7 17 9
Balance	707 1 1
	£778 10 10

November 10, 1881. (Signed) G. M. WHIPPLE.

APPENDIX I.

Magnetic Observations made at the Kew Observatory, Lat. 51° 28′ 6″ *N., Long.* $0^h\ 1^m\ 15^s{\cdot}1$ *W., for the year October* 1880 *to September* 1881.

The observations of Deflection and Vibration given in the annexed Tables were all made with the Collimator Magnet marked K C 1, and the Kew 9-inch Unifilar Magnetometer by Jones.

The Declination observations have also been made with the same Magnetometer, Collimator Magnets N D and N E being employed for the purpose.

The Dip observations were made with Dip-circle Barrow No. 33, the needles 1 and 2 only being used; these are 3½ inches in length.

The results of the observations of Deflection and Vibration give the values of the Horizontal Force, which, being combined with the Dip observations, furnish the Vertical and Total Forces.

These are expressed in both English and metrical scales—the unit in the first being one foot, one second of mean solar time, and one grain; and in the other one millimetre, one second of time, and one milligramme, the factor for reducing the English to metric values being 0·46108.

By request, the corresponding values in C.G.S. measure are also given.

The value of log π^2K employed in the reduction is 1·64365 at temperature 60° F.

The induction-coefficient μ is 0·000194.

The correction of the magnetic power for temperature t_0 to an adopted standard temperature of 35° F. is

$$0{\cdot}0001194(t_0-35)+0{\cdot}000{,}000{,}213(t_0-35)^2.$$

The true distances between the centres of the deflecting and deflected magnets, when the former is placed at the divisions of the deflection-bar marked 1·0 foot and 1·3 feet, are 1·000075 feet and 1·300097 feet respectively.

The times of vibration given in the Table are each derived from the mean of 12 or 14 observations of the time occupied by the magnet in making 100 vibrations, corrections being applied for the torsion-force of the suspension-thread subsequently.

No corrections have been made for rate of chronometer or arc of vibration, these being always very small.

The value of the constant P, employed in the formula of reduction $\frac{m}{X}=\frac{m'}{X'}\left(1-\frac{P}{r_0^2}\right)$, is $-0{\cdot}00109$.

In each observation of absolute Declination the instrumental readings have been referred to marks made upon the stone obelisk erected 1,250 feet north of the Observatory as a meridian mark, the orientation of which, with respect to the Magnetometer, was determined by the late Mr. Welsh, and has since been carefully verified.

The observations have all been made and reduced by Mr. F. G. Figg.

Observations of Deflection for Absolute Measure of Horizontal Force.

Month.	G. M. T.	Distances of Centres of Magnets.	Temperature.	Observed Deflection.	Log $\frac{m}{X}$. Mean.
1880.	d. h. m.	foot.	°	° ′ ″	
October........	28 12 32 P.M.	1·0	54·3	15 34 3	
		1·3	....	7 1 11	9·12956
	2 35 „	1·0	53·6	15 35 7	
		1·3	....	7 1 42	
November......	25 12 20 P.M.	1·0	57·2	15 32 7	
		1·3	....	7 0 28	9·12846
	2 18 „	1·0	55·6	15 31 23	
		1·3	....	6 59 59	
December......	23 12 35 P.M.	1·0	54·3	15 32 31	
		1·3	....	7 0 29	9·12857
	2 27 „	1·0	54·5	15 32 0	
1881.		1·3	....	7 0 28	
January........	28 12 27 P.M.	1·0	41·5	15 33 47	
		1·3	....	7 1 2	9·12826
	2 28 „	1·0	42·9	15 33 8	
		1·3	....	7 0 48	
February	24 12 34 P.M.	1·0	41·0	15 34 55	
		1·3	....	7 1 40	9·12870
	2 37 „	1·0	42·4	15 34 0	
		1·3	....	7 1 11	
March	25 12 26 P.M.	1·0	46·6	15 32 49	
		1·3	....	7 0 42	9·12824
	2 46 „	1·0	48·5	15 32 25	
		1·3	....	7 0 27	
April..........	25 12 38 P.M.	1·0	60·4	15 29 17	
		1·3	....	6 59 8	9·12761
	2 36 „	1·0	62·9	15 28 39	
		1·3	....	6 59 3	
May	26 12 27 P.M.	1·0	65·8	15 29 53	
		1·3	....	6 59 25	9·12787
	3 27 „	1·0	70·5	15 27 31	
		1·3	....	6 58 17	
June	28 12 24 P.M.	1·0	67·3	15 29 50	
		1·3	....	6 59 21	9·12795
	2 37 „	1·0	68·1	15 28 10	
		1·3	....	6 58 31	
July	28 12 27 P.M.	1·0	72·1	15 29 48	
		1·3	....	6 59 19	9·12824
	2 39 „	1·0	73·8	15 27 47	
		1·3	....	6 58 24	
August	26 12 37 P.M.	1·0	68·9	15 28 51	
		1·3	....	6 59 0	9·12778
	2 36 „	1·0	68·2	15 28 16	
		1·3	....	6 58 22	
September......	28 12 28 P.M.	1·0	61·4	15 30 51	
		1·3	....	6 59 50	9·12818
	2 36 „	1·0	63·8	15 29 33	
		1·3	....	6 59 14	

Vibration Observations for Absolute Measure of Horizontal Force.

Month.	G. M. T.	Temperature.	Time of one Vibration.*	Log mX. Mean.	Value of m.†
1880.	d. h. m.	°	secs.		
October..........	28 11 54 A.M.	52·9	4·6468		
	3 12 P.M.	52·2	4·6450	0·30964	0·52432
November........	25 11 39 A.M.	55·8	4·6420		
	2 59 P.M.	55·1	4·6405	0·31071	0·52430
December........	23 12 1 P.M.	53·1	4·6411		
	2 59 P.M.	54·2	4·6406	0·31068	0·52435
1881.					
January..........	28 11 50 A.M.	39·8	4·6365		
	3 2 P.M.	42·6	4·6362	0·31077	0·52422
February	24 11 59 A.M.	39·3	4·6380		
	3 10 P.M.	42·8	4·6368	0·31055	0·52435
March...........	25 11 44 A.M.	45·1	4·6369		
	3 18 P.M.	48·2	4·6384	0·31081	0·52423
April............	25 11 46 A.M.	58·7	4·6429		
	3 8 P.M.	63·4	4·6420	0·31080	0·52385
May.............	26 11 49 A.M.	65·2	4·6451		
	3 54 P.M.	70·1	4·6411	0·31110	0·52418
June	28 11 43 A.M.	67·1	4·6439		
	3 14 P.M.	68·6	4·6412	0·31102	0·52418
July.............	28 11 54 A.M.	71·5	4·6465		
	3 16 P.M.	73·6	4·6425	0·31093	0·52430
August	26 11 50 A.M.	69·7	4·6467		
	3 19 P.M.	69·7	4·6442	0·31065	0·52385
September........	28 11 44 A.M.	59·9	4·6426		
	3 32 P.M.	64·4	4·6419	0·31075	0·52417

* A vibration is a movement of the magnet from a position of maximum displacement on one side of the meridian to a corresponding position on the other side.

† m = magnetic moment of vibrating magnet.

Dip Observations.

Month.	G. M. T.	Needle.	Dip.
	d. h. m.	No.	North. ° ′
1880. Oct.	26 3 16 P.M.	1	67 42·50
	3 16 „	2	42·75
	29 3 7 „	1	43·75
	3 5 „	2	42·93
	Mean..	....	67 42·98
Nov.	29 3 6 P.M.	1	67 43·87
	3 4 „	2	42·25
	30 3 9 „	1	44·06
	3 9 „	2	43·37
	Mean..	....	67 43·39
Dec.	29 2 56 P.M.	1	67 43·18
	2 55 „	2	43·62
	30 2 53 „	1	43·31
	2 52 „	2	43·06
	31 3 7 „	1	42·50
	3 6 „	2	42·31
	Mean..	....	67 43·00
1881. Jan.	25 3 8 P.M.	1	67 41·93
	3 8 „	2	41·37
	26 3 14 „	1	42·43
	3 14 „	2	42·18
	Mean..	....	67 41·98
Feb.	25 3 12 P.M.	1	67 41·87
	3 11 „	2	41·50
	28 3 12 „	1	42·50
	3 13 „	2	42·56
	Mean..	...	67 42·11
Mar.	23 2 59 P.M.	1	67 41·25
	2 59 „	2	41·43
	28 3 1 „	1	41·62
	3 1 „	2	41·37
	Mean..	....	67 41·42

Month.	G. M. T.	Needle.	Dip.
	d. h. m.	No.	North. ° ′
1881. Apl.	27 3 4 P.M.	1	67 39·37
	3 4 „	2	39·68
	29 2 50 „	1	40·87
	2 50 „	2	41·12
	Mean..	....	67 40·26
May	27 2 59 P.M.	1	67 40·31
	2 58 „	2	40·00
	31 3 31 „	1	39·93
	3 30 „	2	39·68
	Mean..	....	67 39·98
June	27 3 20 P.M.	1	67 40·37
	3 19 „	2	39·46
	30 3 38 „	1	40·31
	3 35 „	2	38·93
	Mean..	....	67 39·77
July	27 3 6 P.M.	1	67 40·75
	3 6 „	2	40·00
	29 3 16 „	1	40·93
	3 17 „	2	40·68
	Mean..	....	67 40·59
Aug.	30 3 0 P.M.	1	67 41·59
	3 1 „	2	40·68
	31 3 14 „	1	41·50
	3 14 „	2	40·18
	Mean..	....	67 40·99
Sept.	29 3 3 P.M.	1	67 41·75
	3 6 „	2	41·37
	30 3 37 „	1	40·93
	3 36 „	2	41·37
	Mean..	....	67 41·35

Month.	Declination.	Magnetic Intensity.								
		English Units.			Metric Units.			C. G. S. Units.		
	Mean of Observations.	X, or Horizontal Force.	Y, or Vertical Force.	Total Force.	X, or Horizontal Force.	Y, or Vertical Force.	Total Force.	X, or Horizontal Force.	Y, or Vertical Force.	Total Force.
	West.									
1880.										
October	18° 55′ 47″	3·8908	9·4945	10·2608	1·7940	4·3777	4·7311	0·1794	0·4378	0·4731
November	18 54 47	3·9005	9·5214	10·2892	1·7985	4·3902	4·7442	0·1798	0·4390	0·4744
December	18 52 23	3·8999	9·5168	10·2849	1·7982	4·3880	4·7422	0·1798	0·4388	0·4742
1881.										
January	18 50 13	3·9017	9·5131	10·2821	1·7990	4·3863	4·7409	0·1799	0·4386	0·4741
February......	18 52 49	3·8987	9·5069	10·2752	1·7976	4·3835	4·7377	0·1798	0·4383	0·4738
March........	18 55 26	3·9019	9·5093	10·2787	1·7991	4·3846	4·7394	0·1799	0·4385	0·4739
April	18 55 29	3·9048	9·5074	10·2778	1·8004	4·3837	4·7389	0·1800	0·4384	0·4739
May..........	18 53 29	3·9049	9·5052	10·2761	1·8005	4·3827	4·7382	0·1800	0·4383	0·4738
June	18 49 27	3·9042	9·5019	10·2726	1·8002	4·3812	4·7365	0·1800	0·4381	0·4736
July..........	18 48 23	3·9025	9·5041	10·2740	1·7994	4·3822	4·7372	0·1799	0·4382	0·4737
August	18 50 26	3·9033	9·5091	10·2792	1·7997	4·3845	4·7396	0·1800	0·4384	0·4740
September	18 46 54	3·9020	9·5089	10·2785	1·7992	4·3844	4·7393	0·1799	0·4384	0·4739

APPENDIX II.

Meteorological Observations.—Table I.

Kew Observatory.

Longitude $0^h\ 1^m\ 15^s{\cdot}1$ W. Latitude 51° 28′ 6″ N. Height above sea-level =34 feet.

Mean Monthly results from the continuous Records for the Twelve Months ending September 30th, 1881.

Months.	Thermometer.* Means.	Thermometer.* Extreme maximum. Date.	Extreme maximum. Ther.	Extreme minimum. Date.	Extreme minimum. Ther.	Barometer.† Means.	Barometer.† Extreme maximum. Date.	Extreme maximum. Bar.	Extreme minimum. Date.	Extreme minimum. Bar.	Pressure. Means. Vapour-tension.	Pressure. Means. Dry air.
	°	d. h.	°	d. h.	°	inches.	d. h.	inches.	d. h.	inches.	inch.	inches.
1880. October....	46·5	7 3 P.M.	64·1	24 7 A.M.	30·7	29·890	14 10 A.M.	30·433	28 10 A.M.	28·767	·268	29·622
November..	42·7	13 noon	57·5	22 8 „	25·2	29·977	21 5 „	30·493	16 2 P.M.	28·738	·229	29·748
December..	43·3	10 2 P.M.	55·5	22 1 „	26·0	29·940	7 11 P.M.	30·680	29 8 „	29·071	·242	29·698
1881. January....	31·8‡	31 3 „	48·8	17 9 „	9·4	29·902	7 {8 „ / 9 „}	30·623	29 3 „	28·868	·152	29·750
February...	38·2	3 1 „	52·3	7 5 „	26·4	29·848	24 {10 A.M. / 11 „}	30·312	11 5 A.M.	28·914	·199	29·649
March.....	42·5	18 3 „	59·2	1 6 „	25·1	29·910	{17 midt. / 18 1 A.M.}	30·565	7 5 P.M.	29·134	·213	29·697
April......	45·8	13 1 „	66·8	21 5 „	29·9	29·956	28 10 „	30·270	30 8 „	29·645	·219	29·737
May......	53·9	31 5 „	76·1	4 4 „	31·5§	30·107	10 11 P.M.	30·680	16 4 A.M.	29·410	·283	29·824
June......	58·7	4 4 „	78·2	9 4 „	38·5	29·984	30 3 A.M.	30·335	6 4 „	29·433	·339	29·645
July.......	64·9	5 2 „	90·0	28 5 „	44·1	30·004	14 9 „	30·336	31 5 P.M.	29·494	·400	29·604
August....	58·9	5 {2 „ / 3 „ / 4 „}	80·7	28 5 „	43·1	29·854	4 9 „	30·349	26 3 A.M.	29·372	·378	29·476
September..	55·5	18 4 „	71·3	30 4 „	39·4	29·984	29 {9 „ / 10 „}	30·430	21 8 „	29·441	·363	29·621
Means.........	48·6	....	..	....	..	29·946	....	..	....	..	·274	29·672

The above Table is extracted from the Quarterly Weather Report of the Meteorological Office, by permission of the Meteorological Council.

* The thermometer-bulbs are 10 feet above the ground.

‡ One of the daily means somewhat doubtful.

† Readings reduced to 32° at mean sea-level.

§ Reading somewhat doubtful.

Meteorological Observations.—Table II.

Kew Observatory.

Months.	Mean amount of cloud (0=clear, 10=overcast).	Rainfall *.			Weather †. Number of days on which were registered						Wind ‡. Number of days on which it blew							
		Total.	Maximum.	Date.	Rain.	Snow.	Hail.	Thunderstorms.	Clear sky.	Overcast sky.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
1880.		in.	in.															
October ..	7·6	5·945	1·080	9	18	2	..	..	1	20	3	13	2	..	1	4	4	4
November	6·4	1·785	0·560	18	15	..	..	..	5	14	5	4	1	1	3	11	3	2
December	7·6	3·300	0·650	29	13	5	..	..	2	22	2	2	1	1	1	12	9	3
1881.																		
January ..	6·9	1·170	0·500	18	6	5	..	..	5	18	3	7	6	1	2	4	4	4
February .	8·8	2·540	0·645	20	11	4	..	..	..	23	5	5	2	4	3	4	2	3
March ...	6·5	1·980	0·535	4	9	2	2	1	6	14	1	4	8	1	2	3	10	2
April	6·7	0·765	0·275	11	9	..	1	1	..	11	2	10	5	1	2	4	3	3
May	5·9	1·115	0·330	28	10	..	1	2	8	12	3	5	7	1	..	10	2	3
June	6·9	1·620	0·530	6	11	..	1	2	2	14	3	2	2	1	5	9	6	2
July	5·9	1·915	0·675	5	13	..	..	1	3	9	2	1	1	..	2	9	10	6
August ..	7·4	4·770	1·240	12	17	..	..	3	1	15	3	1	..	1	2	11	10	3
September	6·9	2·215	0·580	24	17	..	..	1	4	14	6	4	2	1	2	4	4	7
Totals..		29·120			149	18	5	11	37	186	38	58	37	13	25	85	67	42

* Measured daily at 10 A.M. by gauge 1·75 feet above surface of ground. † Derived from observations made at 10 A.M., noon, 2, 4, and 10 P.M.

‡ As registered by the anemograph.

Meteorological Observations.—Table III.

Kew Observatory.

Months.	Bright Sunshine.*		Maximum temperature in sun's rays.			Minimum temperature on the ground.			Horizontal movement of the Air.†		
	Total number of hours.	Number of hours Sun was above the horizon.	Mean.	Highest.	Date.	Mean.	Lowest.	Date.	Average daily Velocity.	Greatest Movement in a day.	Date.
1880.	h. m.	h. m.	deg.	deg.		deg.	deg.		miles.	miles.	
October	68 7	330 53	85·6	113·0	3	37·9	22·9	24	227	538	9
November	67 1	263 47	76·5	93·9	25	31·1	19·1	2	278	626	14
December	32 8	242 51	65·6	89·2	10	34·3	22·7	22	258	505	29
1881.											
January	33 3	259 12	56·6	88·0	31	22·4	7·0	17	230	1017	18
February	27 6	278 8	63·7	95·1	10	31·2	20·0	7	265	697	8
March	111 6	367 20	92·6	112·0	10	32·0	18·8	27	289	568	7
April	133 5	415 30	105·8	125·0	13	34·0	23·9	21	356	749	3
May	224 4	482 27	119·3	131·0	21	40·2	24·4	11	277	563	23
June	214 2	494 32	125·3	137·1	26	46·5	34·3	9	213	454	22
July	251 0	496 46	129·1	143·6	5	51·5	37·0	28	205	409	31
August	160 4	448 5	119·5	133·7	4	47·2	35·6	28	223	429	26
September	95 1	377 13	107·0	127·7	25	45·6	36·3	16	152	412	1

* Registered by the Sunshine-recorder.

† As indicated by a Robinson's anemograph, 70 feet above the general surface of the ground.

Presents, November 17, 1881.

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December 8, 1881.

THE PRESIDENT in the Chair.

The President announced that he had appointed as Vice-Presidents:—

The Treasurer.
Sir Risdon Bennett.
Dr. Hirst.
Professor Huxley.
Professor Roscoe.

Dr. Alexander Macalister and Mr. Bernhard Samuelson were admitted into the Society.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read:—

I. "On the Genus *Culeolus*." By W. A. Herdman, D.Sc., F.L.S., F.R.S.E., Demonstrator of Zoology in the University of Edinburgh. Communicated by Professor Sir Wyville Thomson, F.R.S. Received November 1, 1881.

(Abstract.)

The genus *Culeolus* has been formed for a series of six new species of pedunculated Simple Ascidians, belonging to the family Cynthiidæ, and having several anatomical peculiarities distinguishing them from all hitherto described genera. The nearest ally of *Culeolus* is *Boltenia*, and these two genera have been placed together as a sub-family, the Bolteninæ, characterised as Cynthiidæ which have the body pedunculated, the tentacles compound, and the branchial sac with more than four folds on each side.

Culeolus is distinguished from *Boltenia* by its remarkable branchial sac (which will be described shortly), and by the external character that its branchial aperture is triangular, and its atrial aperture bilabiate, while in *Boltenia* both apertures are four-lobed.

One of the species, *Culeolus murrayi*, is described in detail—anatomical and histological—while the other five are not so fully treated, but the different systems in each are compared with those of the type, and the modifications are pointed out. The following are a few of the more interesting peculiarities of the genus:—

As regards the test, the disposition of the blood-vessels is the most important feature. In *Culeolus murrayi*, throughout the greater part of the test, blood-vessels are few and feebly developed. In the superficial layer, however, the terminal twigs open into an enormously developed system of globular cavities, separated by extremely thin walls from the external medium, and in direct connexion with the delicate hollow papillæ projecting from the outer surface of the test. The globular cavities and their prolongations, the papillæ, contain masses of blood-corpuscles, and there can be little doubt that the whole system acts, to a certain extent, as an accessory organ of respiration. In another species, *C. wyville-thomsoni*, the vessels are much more developed throughout the thickness of the test, while the number of globular cavities in the superficial layer is very small. The terminal twigs of the vessels, however, are prolonged beyond the general surface in the form of a series of delicate and minute finger-like processes, which, over some parts of the surface, are present in great numbers. These are evidently a modification of the large papillæ of *C. murrayi*, and both are homologous with the long hair-like processes found on the outer surface of the test in most of the Molgulidæ.

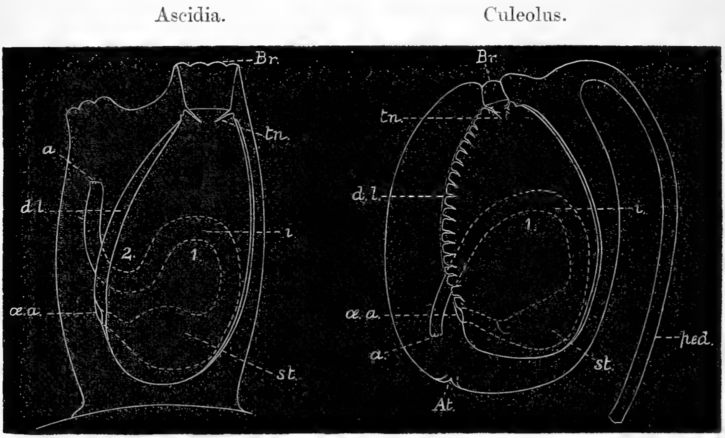
The branchial sac is the most characteristic organ of the genus, and is of great morphological interest. As it belongs to the Cynthiad type, it is necessarily so far complicated as to possess a certain number of longitudinal folds on each side, but in all other respects it is the simplest form of branchial sac known among Simple Ascidians.

Neglecting for the moment the longitudinal folds, the organ may be described as a simple network, formed by two series of vessels crossing at right angles and communicating at the points of intersection. The two series are the horizontal or transverse vessels, which are sometimes of two or more sizes occurring alternately, and the internal longitudinal bars which run vertically and generally form the strongest part of the network. This is the structure of the branchial sac between two folds in the simplest form, *Culeolus murrayi*, and the great difference between it and the simplest form of branchial sac in the genus *Ascidia* (*e.g.*, *A. cylindracea* or *A. venosa*, where minute longitudinal plication of the sac is not present) lies in the fact that in *Culeolus* no fine longitudinal vessels are present, and consequently the meshes are not broken up into stigmata. In two of the species, however, here and there over the branchial sac, a mesh was found divided more or less irregularly by a delicate longitudinal vessel crossing from one transverse vessel to the adjacent one. These cases were rare, and evidently abnormalities, but they indicate a tendency towards the division of the mesh into stigmata through the development of fine longitudinal vessels. In *Culeolus perlucidus* this process has taken place. Here each mesh is divided into two equal areas by a delicate longitudinal vessel running between the transverse vessels. In this species, consequently, one might correctly describe the branchial sac as having two stigmata in each mesh. Along the free edges of the internal longitudinal bars the epithelium is cubical or low columnar, but never ciliated.

One peculiarity of the branchial sac throughout the genus remains to be mentioned. That is the presence in its vessels of an extensively developed system of calcareous spicules. These are of considerable size, often much ramified, and have a very characteristic appearance from their gentle curves and blunt ends. They vary in size, abundance, and amount of branching according to the species; and are chiefly developed in the internal longitudinal bars, and along the edges of the endostyle.

The dorsal lamina throughout the genus is represented by a series of triangular languets.

The alimentary canal from the œsophageal opening onwards, though differing somewhat in its details in the different species, has in all the same general course. It lies on the left side of the branchial sac, in its posterior half, and nearer to the ventral than the dorsal edge. The œsophageal aperture (*œ.a.*) lies far back in the branchial sac, at the posterior end of the dorsal lamina (*d.l.*) The œsophagus is short, and runs ventrally to open into the large stomach (*s.t.*) which lies along the ventral edge of the branchial sac. The intestine (*i.*) runs anteriorly from the stomach for a certain distance, and then, turning towards the dorsal region, returns parallel to its first part towards the posterior end, and finally terminates near the posteriorly placed atrial aperture (*At*).



The annexed diagrams show the relation of the course of the intestine in *Culeolus* to the arrangement found in *Ascidia*. The chief difference is that in the latter genus the intestine, after running posteriorly for a short distance, takes a final curve anteriorly, thus making a second loop (2), open anteriorly, which is entirely wanting in *Culeolus*. The cause of the difference is obviously the position of the atrial aperture (*At.*) This lies in *Culeolus* almost at the posterior end of the body, and consequently the last part of the intestine runs posteriorly. In *Ascidia*, on the other hand, the atrial aperture is usually situated near the anterior extremity, therefore the intestine is necessarily twisted forwards again so that it may terminate near the common excretory aperture.

All the species of *Culeolus* are from upwards of 600 fathoms; five are from over 1,000 fathoms, four from over 1,500, and two from upwards of 2,000 fathoms. They all belong to the abyssal fauna.

It is noteworthy that these six species, the only deep-water Bolteninæ, all belong to one genus, notwithstanding their wide distribution in space—one species being from the North Atlantic, two from the Southern Ocean, one from the South Pacific, one from the North Pacific, and one from the centre of the Pacific Ocean on the Equator.

II. "On the Development of the Skull in *Lepidosteus osseous.*" By W. K. Parker, F.R.S.

Received November 3, 1881.

(Abstract.)

The materials for the present paper were kindly sent to me by Professor A. Agassiz; they were for the use of Mr. Balfour and myself, and consisted of *fifty-four* small bottles of eggs and embryos in various stages. These very valuable materials were obtained from Black Lake by Mr. S. W. Garman and Professor Agassiz, and many of the embryos were described and figured by the latter in the "Proceedings of the American Academy of Arts and Sciences," October 8, 1878.

Having received from my friend the author a copy of his important paper, I at once wrote to ask permission to work his materials out, thoroughly; suggesting that Mr. Balfour would undertake the embryological part of the work.

On receipt of my letter Professor Agassiz kindly acceded to my wish, and the results of our investigations are now ready for publication.

Mr. Balfour's part of the work has been done with the assistance of my son, Mr. W. N. Parker, and their joint labour will include the anatomy of various organs of the adult fish.

We have had additional materials from Professor Burt G. Wilder; these were larger young than those supplied by Professor Agassiz; Mr. Balfour also has obtained several adult fishes in spirit; and I am indebted to Professor Flower for an adult in the dry state.

Finding that we were in a condition to do some useful research on this important *Holostean Ganoid*, I pressed Dr. Traquair to take up the skull of the adult; this he consented to do; and I am daily expecting that his paper will be sent to the Royal Society.

My observations on the skull and visceral arches have been made on embryos and young, varying from one-third of an inch to 4½ inches in length; I have (artificially) divided these into *six stages*. Cartilage was being formed in the smallest examined by me, but in my second stage, embryos five-twelfths of an inch long, this tissue was quite consistent, and I succeeded in dissecting out all the parts. The large notochord at this stage bends downwards under the swelling hind-brain, and then turns up a little at its free end; passing into the lower part of the fissure between the mid- and hind-brain, it reaches beyond the middle of the cranium, and just touches the infundibulum and *distinct* pituitary body.

The paired cartilages, "parachordals," that invest the notochord only cleave to its hinder *three-fifths*; these bands then diverge and

enclose a lanceolate space under the fore-brain ("thalamencephalon"). These somewhat flattened bands of cartilage become narrower up to the middle of this large primary "pituitary space," and then recover their former width in front, where they come in contact, having no notochord between them. All the cartilage that lies in front of the notochord is called *trabecular;* between the trabeculæ, in front, there is a small wedge of younger cartilage, the rudiment of the "inter-trabecula." The hinder, or *parachordal*, parts are somewhat scooped and bevelled above, and on their edge the auditory capsules rest. These are quite distinct, and have a cartilaginous coat, which, however, has a large oval deficiency below. As in the Batrachia, the fore part of the "palato-quadrate" cartilages is continuous with the trabeculæ in front; but the "pedicle" is free behind. The free "articulo-Meckelian" rod is quite in front of the eye-balls, and is nearly as long as the hind suspensorium, or proper quadrate region; this forward position of the hinge of the mandible is not temporary as in the frog, but is permanent. The uppermost element of the hyoid arch is an anvil-shaped cartilage from the first, and ossifies afterwards, as the hyo-mandibular and symplectic bones. As pointed out to me by Mr. Balfour, its dorsal end is continuous, *as cartilage*, with the skull (auditory capsule) above. The basi-hyal is not yet ossified, but distinct inter-cerato- and hypo-hyal segments are already marked out. Four larger and one small rods of cartilage are seen on each side, articulating with a median band; these are the branchial arches, which chondrify before they undergo segmentation. In this stage there are no osseous laminæ as yet formed.

Here, in this stage, in connexion with a large *pre-nasal* suctorial disk, we have three important generalised characters, namely, the continuity of the distal end of the mandibular pier and of the proximal end of the hyoid pier with the skull, and the forward position of the hinge of the jaw coupled with the horizontal direction of the suspensorium. The hyoid arch has its segments formed much earlier than in the Teleostei, and the "pharyngo-branchials" are not independent cartilages, as in the *Skate*.

The third stage—embryos two-thirds of an inch long—show a considerable advance in the development of the skull; the cartilage, generally, is more solid and more extensive, and new tracts have appeared. The apex of the notochord is now in the middle of the basis cranii, for the *pro*chordal tracts have grown faster than the *para*chordals. The large so-called pituitary space is now irregularly pyriform, and not lanceolate: the fore margin of the broad parachordal bands being now nearly transverse, whilst the prochordals (*trabeculæ*) are wide and fenestrate at first, then narrow, and then widening suddenly, they coalesce, forming a sharp anterior end to the pituitary space.

Behind, the parachordals have grown further along the thick notochord, and on each side they are now confluent with the auditory capsules, which have become irregularly ovoidal through the growth of the large semicircular canals within; their basal fenestra is still a round space under the partially floored "sacculus." The trabeculæ swell out where they are confluent, and then are narrower in front again. At their fore end each band passes insensibly into the corresponding palato-quadrate bar outside, whilst inside they are separated by a large pyriform wedge of cartilage, the intertrabecula. The thick, rounded, free fore end of this median cartilage is the rudiment of the great "nasal rostrum," and the rounded fore ends of the trabeculæ are the rudiments of their "cornua."

There is only a floor in the occipital region, but the *wall-plate* of the chondrocranium has begun as a styloid cartilage running forward from the fore end of each auditory capsule into the superorbital region. The palato-pterygoid band—continuous in front with the trabeculæ—is now longer than the proximal part of the suspensorium, the spatulate quadrate region whose dorsal end is the free "pedicle." The wide proximal part of each trabecula is now already forming an oblong facet, the "basi-pterygoid," for articulation with the facet of the "pedicle."

An oblong concavity is now seen under the outer edge of each auditory capsule, for the oblong head of the hyomandibular whose body is still solid, and the "symplectic" part merely a process growing downwards and forwards to get inside the lower margin of the suspensorium of the mandible. The epi-hyal region is still merely the top of the cerato-hyal; it is afterwards separate as a bony centre; the inter-hyal, hypo-hyal, and *double* basi-hyal are all now chondrified and distinct, but the branchial arches are not yet segmented. In this stage the skull is a curious compromise between that of a Salmon at the same stage and that of a Tadpole just beginning its transformation. The hind-skull is quite like that of a young Salmon, the fore-skull, with its non-segmented palato-quadrate, and its forwardly placed quadrate condyles and horizontal suspensorium, is very much like what is seen in the suctorial skull of the *Anurous larva;* a splint bone, the parasphenoid, as in the Tadpole, has now made its appearance.

The largest embryos reared by Messrs. Agassiz and Garman, which are about one inch in length, form my *fourth* stage; these are rapidly acquiring the characters of the adult.

This is the stage in which the chondrocranium of this Holostean type corresponds most closely with that of the Chondrostean Sturgeon, whose adult skull is similar to that of Garpike just as the latter begins to show its own special characters. This important difference is already evident, namely, that whilst in *Acipenser* the olfactory capsules remain in the *antorbital* position, those of *Lepidosteus* are already carried forwards by the growing intertrabecula, and are even now in front of the relatively huge "cornua trabeculæ." Thus these regions are now well grown in front of the ethmoidal territory, which, instead of being, as in the last stage, in the front margin of the skull, is now fairly in its middle, and this change has taken place whilst the embryo has only become one-half larger—from two-thirds of an inch to an inch in length. It is the hypertrophy of cartilage in the three trabecular tracts that makes the "rostrum" of the Sturgeon so massive, even whilst only a few inches in length, and this state of things exists temporarily in the Garpike.

Each "cornu" is now like a thick succulent lanceolate leaf, coiled partly upon itself, downwards, at its outer edge; the middle bar, or intertrabecula, is now half as long as the skull, and projects forwards beyond the cornua, and between the distally-placed olfactory capsules. The cranial cavity is now relatively very large, and is covered by a cartilaginous "tegmen," before and behind; between these regions, over the huge mid-brain, there is a sub-circular "fontanelle," narrower in front than behind, and emarginate in front by some growth of cartilage in the mid-line.

The postorbital spike of cartilage has now grown into a narrowish superorbital band, bounding the upper fontanelle and enclosing between itself and the trabecula, below, a large "orbito-sphenoidal" fenestra. The floor is also still open, and this large pituitary space is spearhead-shaped, and is under-floored by the parasphenoid.

The basipterygoid processes are now well formed; the basal cartilages (parachordals) now embrace the huge notochord below, the flaps approaching, but not touching, each other. The notochord is now being formed into a "cephalostyle," but the bony sheath is imperfect. Above, the sphenotic, epiotic, and opisthotic projections of the auditory capsule are more evident, but are not ossified. Some slight bony deposit has appeared in the prootic region. The "cephalostyle" is the first *endo*-cranial bone, and the parasphenoid the first *ecto*-cranial centre; but the exoccipitals are just appearing also. The condyle of the quadrate is now still further behind the middle of the palato-quadrate arcade, the pterygopalatine part of which is now quite free in front, and has grown forwards parallel with the rostrum, as a long style, which reaches further *forwards* than the cornua trabeculæ. The "pedicle" of the suspensorium has a facet by which it articulates with the basipterygoid. The mandibular cartilage has also grown equally with the freed pterygopalatine rod, and has now a very large ear-shaped *coronoid* part in front of and above the articular part. The opercular process and fenestra of the hyomandibular are now formed, but this part is not ossified; the cerato-hyal diaphysis is present. It is the only *shaft-bone* in the hyoid arch as yet; the branchial arches are segmenting. The superficial bones can now be seen as fine films in the transverse sections, and the *parosteal palatine* and pterygoid are large leaves of bone applied to the pterygopalatine bar; the mesopterygoid is only half as large as them, but is relatively much larger than in the adult.

Whilst doubling its length, the young *Lepidosteus* gains a cranium much more like that of the adult; this is my *fifth* stage. The general form is now intensely modified by the foregrowth of the rostrum: the "intertrabecula" is now *two-thirds* the length of the entire skull. The cornua trabeculæ now reach only *two-fifths* of the distance to the end of the beak, and the pterygopalatine arcade reaches but little further forwards. Owing to the "tegmen cranii" being much larger, the upper fontanelle is much smaller; it is now a short oval, its longer diameter being lengthwise. The bony matter of the "cephalostyle" is now aggregated towards the hinder half of the notochord; it is now the basi-occipital bone. The exoccipitals and prootics are growing larger, and there are now both sphenotics and alisphenoids. Also, below, the quadrate, metapterygoid, and articular "centres" have appeared; and behind the jaw there are the hyomandibular, symplectic, epi-hyal, cerato-hyal, and hypo-hyal centres; and the epi-, cerato-, and hypo-branchials have acquired a bony sheath.

In a young *Lepidosteus* $4\frac{1}{2}$ inches long (nearly), the approach to the adult state of the skull has been very great; the superficial bones can all be determined. The most remarkable of these are the small distal nasals and premaxillaries; the long *maxillary chain*, ending in an "os mystaceum and jugal"; the extremely long and slender "ethmo-nasals" and vomers; the small pre-opercular; and the huge angulated inter-opercular, which carries the large opercular and sub-opercular. The five mandibular splints are all present (as in most Sauropsida), the branchiostegals are only three in number, as in the Carp tribe.

The intertrabecula, which was merely a small tract of cells binding the trabeculæ together, in front, is now *three-fourths* the length of the entire skull; to it is due the length of the *beak*. The cornua trabeculæ are now merely short lanceolate leafy growths on the sides of the rostrum at its hind part. In the last stage there was a fine bridge of cells running across behind the pituitary body; this is now a small cartilaginous "post-clinoid" bar. The opisthotic and epiotic form now a scarcely divided tract of bone, all the other centres are developing, and a pair of additional bones have appeared in the funnel-shaped fore-end of the chondrocranium; these are the "lateral ethmoids." The bony matter of the basi-occipital has now retired to the hinder third of the notochord, which has much shrunken.

There are now two centres (as in *Amia calva*) in the articular region of the mandible; the quadrate and metapterygoid centres are much larger; the hyo-mandibular and symplectic are together only half the size of the mandibular suspensorium; the basi-hyal is very large, is composed of two parallel pieces, and is very *Myxinoid.*

Brief and imperfect as this "Abstract" is, I trust it is sufficient to show the extremely interesting and suggestive nature of this type; anyhow, no clear understanding of the morphology of this type of skull can be had unless it be seen in the light derived from that of the Elasmobranchs, the Sturgeon, and the Anurous larva on one hand, and that of *Amia calva* and the Teleostei on the other.

III. "On the Structure and Development of *Lepidosteus.*" By F. M. Balfour, LL.D., F.R.S., and W. N. Parker. Received November 24, 1881.

(Abstract.)

The authors commence this paper by thanking Professor Alexander Agassiz for the material, both embryological and adult, on which these researches were made.

The first section is devoted to the general development. In this section an account is given of the structure of the ripe ovum, of the segmentation, of the history of the germinal layers, of the first development of the principal organs, and of the external features of the embryo during embryonic and larval life. The more important points established in this section, are—

(1.) The ovum when laid is invested by a double covering formed of (*a*) a thick inner membrane, the outer zone of which is radially striated, and (*b*) an outer layer made up of highly refractive pyriform bodies which are probably metamorphosed follicular epithelial cells.

(2.) The segmentation is complete, though very unequal; the lower pole being very slightly divided into segments, and its constituent parts subsequently fusing together to form an unsegmented mass of yolk, like the yolk-mass of Teleostei.

(3.) The epiblast is divided into an epidermic and a nervous stratum, as in Teleostei.

(4.) The walls of the brain, of the spinal cord, and of the optic vesicles are formed from a solid medullary keel, like that found in Teleostei.

(5.) The lens, the auditory vesicle, and the olfactory pit, are wholly developed from the nervous layer of the epidermis.

(6.) The segmental or archinephric duct is developed, as in Teleostei, from a hollow ridge of the somatic mesoblast, which becomes constricted off, except in front; thus forming a duct with an anterior pore leading into the body cavity.

The section on the general development is followed by a series of sections on the adult anatomy and development of various organs.

The Brain.

The authors give a fuller description of the adult brain than previous anatomists. The new features in this description are (1) that the parts identified by previous anatomists as the olfactory lobes, are really parts of the cerebral hemispheres; the true olfactory lobes being small prominences at the base of the olfactory nerves; (2) that there is attached to the roof of the thalamencephalon a peculiar vesicle, which has not hitherto been noticed, but which is similar to the vesicle found by Wiedersheim on the roof of the thalamencephalon of Protopterus. They further show that the cerebrum is divided into a posterior portion, with an unpaired ventricle, and an anterior portion in which the ventricle is paired. They consider the presence of a portion of the cerebrum with an unpaired ventricle, to be an indication that this part of the brain retains characters which are only found in the embryonic brain of other groups. They point to the presence of lobi inferiores on the infundibulum, of tori semicirculares in the mid-brain, and of a large cerebellum as indications of an affinity between the brain of Lepidosteus and that of Teleostei. In the embryological section full details are given as to the development of the thalamencephalon, the pineal gland, the cerebrum, and the olfactory lobes.

At the end of the section the characters and affinities of the Ganoid brain are dealt with at some length; and the authors attempt to show that brains of Ganoids are distinguished (1) by the large size of the thalamencephalon, and (2) by the cerebrum being divided into an unpaired portion behind and a paired portion in front.

Organs of Special Sense.

Olfactory Sacs.—An account is given of the development of the olfactory sacs, in which these sacs are shown to originate as invaginations of the nervous layer of the epiblast; the communication between the sacs and the exterior being effected by the rupture or absorption of the superficial epidermic layer of the epiblast. The double opening of these sacs in the adult is described as arising from the division of the primitive single opening. The olfactory nerve arises as an outgrowth of the brain prior to the first differentiation of the olfactory bulb as a special lobe of the brain.

Eye.—In the adult eye a vascular membrane is described bounding the retinal aspect of the vitreous humour. This membrane is supplied by an artery piercing the retina close to the optic nerve, and the veins from it fall into a circular vessel placed at the insertion of the iris. The membrane itself is composed of a hyaline ground substance with numerous nuclei.

In the developmental section devoted to the eye the main subject dealt with is the nature of the mesoblastic structures entering the cavity of the optic cup, through the choroid slit. It is shown that a large non-vascular mesoblastic process first enters the optic cup, and that together with the folded edge of the choroid slit it forms a rudimentary and provisional *processus falciformis*. At a later period an artery, bound up in the same sheath as the optic nerve, enters the optic cup, and the vascular membrane found in the adult then becomes developed.

The Suctorial Disk.

The structure of a peculiar larval suctorial organ, placed at the end of the snout, is described, and the organ is shown to be formed of papillæ composed of elongated epidermic cells, which are probably glandular (modified mucous cells), and pour out a viscid secretion.

Muscular System.

The lateral muscles of Lepidosteus are shown to differ from those of other fishes, except the Cyclostomata, in *not* being divided into a dorso-lateral and ventro-lateral group, on each side of the body.

Vertebral Column and Ribs.

This section of the paper commences with a description of the vertebral column and ribs of the adult. In this part special attention is called to a series of cartilaginous elements, placed immediately below the ligamentum longitudinale superius, which appear to have escaped the notice of the anatomists who have previously worked at Lepidosteus. These elements are shown to be intervertebrally situated.

With reference to the ribs the authors point out that for the greater part of their length they course along the bases of the intermuscular septa, immediately external to the peritoneal membrane, but that their free extremities bend outwards and penetrate between the muscles along the intermuscular septa till they nearly reach the skin.

In the embryological part of this section a detailed account is given of the development of the vertebral column, of which the following is a summary:—

There is early formed round the notochord a mesoblastic investment which is produced into two dorsal and two ventral ridges, the former uniting above the spinal cord. Around the cuticular sheath of the notochord, an elastic membrane, the membrana elastica externa, is next developed. The neural ridges become enlarged at each intermuscular septum, and these enlargements soon become converted into cartilage, thus forming a series of neural processes, riding on the membrana elastica externa, and extending about two-thirds of the way up the sides of the spinal cord. Hæmal processes arise simultaneously with and in the same manner as the neural: they are small in the trunk, but at the front end of the anal fin they suddenly enlarge and extend ventralwards. Behind this point each succeeding pair of hæmal processes becomes larger than the one in front, each process finally meeting its fellow below the caudal vein, thus forming a completely closed hæmal arch. These arches are, moreover, produced into long spines supporting the fin-rays of the caudal fin, which thus differs from the other unpaired fins in being supported by parts of the vertebral column, and not by separately formed skeletal elements.

In the next stage which the authors have had the opportunity of studying (a larva of $5\frac{1}{2}$ centims.), a series of well-marked *vertebral* constrictions are to be seen in the notochord. The sheath is now much thicker in the vertebral than in the intervertebral regions: this being due to a special differentiation of a superficial part of the sheath, which appears more granular than the remainder, and forms a cylinder in each vertebral region. Between it and the gelatinous tissue of the notochord there remains a thin unmodified portion of the sheath, which is continuous with the intervertebral parts of the sheath. The neural and hæmal arches which are of course placed in the vertebral regions are now continuous with a cartilaginous tube embracing the intervertebral regions of the notochord, and continuous from one vertebra to the next. A delicate layer of bone, developed in the perichondium, invests the cartilaginous neural arches, and this bone grows upwards so as to unite above with the osseous investment of separately developed bars of cartilage, which are directed obliquely backwards. These bars, or dorsal processes, may be reckoned as parts of the neural arches. Between the dorsal processes of the two sides are placed median rods of cartilage, which are developed separately from the true neural arches, and which constitute the median spinous elements of the adult. Immediately below these rods is placed the ligamentum longitudinale superius. There is now the commencement, not only in the tail, but also in the trunk, of a separation between the dorsal and ventral parts of the hæmal arches where the latter pass ventralwards, on each side of the body cavity, along the lines of insertion of the intermuscular septa. They are obviously the ribs of the adult, and there is no break of continuity of structure between the hæmal arches of the tail and the ribs. In the anterior part of the trunk, the ribs pass outwards along the intermuscular septa till they reach the epidermis. Thus the ribs are originally continuous with the hæmal processes. Behind the region of the ventral caudal fin the two hæmal processes merge into one, which is not perforated by a canal.

Each of the intervertebral rings of cartilage becomes eventually divided into two parts, which are converted into the adjacent faces of contiguous vertebræ, the curved line where this will be effected being plainly marked out at a very early stage. As these rings are formed originally by the spreading of the cartilage from the primitive neural and hæmal processes, the intervertebral cartilages are clearly derived from the neural and hæmal arches. The intervertebral cartilages are thicker in the middle line than at their two ends.

In the latest stage examined (11 centims. long) the vertebral constrictions of the notochord are rendered much less conspicuous by the intervertebral cartilages giving rise to marked intervertebral constrictions. In the intervertebral regions the membrana elastica externa has become aborted at the posterior border of each vertebra, and the remaining part is considerably puckered transversely. The inner sheath of the notochord is puckered longitudinally in the intervertebral regions. The granular external layer of the sheath in the vertebral regions is less thick than in the last stage, and exhibits a faint radial striation.

Two closely approximated cartilaginous elements now form a keystone to each neural arch above; these are directly differentiated from the ligamentum longitudinale superius, into which they merge above. An osseous plate is formed on the outer side of each of these cartilages. These plates are continuous with the lateral osseous bars of the neural arches, and give rise to the osseous part of the roof of the spinal canal of the adult. Thus the greater part of the neural arches is formed by membrane bone.

The hæmal arches are invested by a thick layer of bone, and there is also a continuous osseous investment round the vertebral portions of the notochord. The intervertebral cartilages become penetrated by branched processes of bone.

The embryological part of this section is followed by a comparative part treated under three headings. In the first of these the vertebral column of Lepidosteus is compared with that of other forms; and it is pointed out that there are grave difficulties in the way of comparing the vertebræ of Lepidosteus with those of the Urodela, in the fact that in Lepidosteus the intervertebral cartilages originate from the bases of the arches, while in the Urodela they are stated by Götte to be thickenings of a special cartilaginous investment of the notochord, which would seem to be homologous with that cartilaginous sheath which is placed in Elasmobranchii and Dipnoi *within* the membrana elastica externa. On the other hand, the development of the vertebræ of Lepidosteus is shown to resemble in most features that of Teleostei, from which it mainly differs in the presence of intervertebral cartilaginous rings.

In the second section, devoted to the homologies of the ribs of Pisces, the conclusions arrived at are summed up as follows:—

The results of the authors' researches appear to leave two alternatives as to the ribs of fishes. One of these, which may be called Götte's view, may be thus stated:—The hæmal arches are homologous throughout the Pisces; in Teleostei, Ganoidei, and Dipnoi the ribs, placed on the inner face of the body wall, are serially homologous with the ventral parts of the hæmal arches of the tail; in Elasmobranchii, on the other hand, the ribs are neither serially homologous with the hæmal arches of the tail, nor homologous with the ribs of Teleostei and Ganoidei, but are outgrowths of the hæmal processes into the space between the dorso-lateral and ventro-lateral muscles, and outgrowths which may perhaps have their homologies in Teleostei and Ganoids in certain accessory processes of the vertebræ.

The other view, which the authors are inclined to adopt, is as follows:—The Teleostei, Ganoidei, Dipnoi, and Elasmobranchii are provided with homologous hæmal arches, which are formed by the coalescence below the caudal vein of simple prolongations of the primitive hæmal processes of the embryo. The canal enclosed by the hæmal arches can be demonstrated embryologically to be the aborted body cavity.

In the region of the trunk the hæmal processes and their prolongations behave somewhat differently in the different types. In Ganoids and Dipnoi, in which the most primitive arrangement is probably retained, the ribs are attached to the hæmal processes, and are placed immediately without the peritoneal membrane, at the insertion of the intermuscular septa. These ribs are in many instances (Lepidosteus, Acipenser), and very probably in all, developed continuously with the hæmal processes, and become subsequently segmented from them. They are serially homologous with the ventral parts of the hæmal arches of the tail, which, like them, are in many instances (Ceratodus, Lepidosteus, Polypterus, and to some extent in Amia) segmented off from the basal parts of the hæmal arches.

In Teleostei the ribs have the same position and relations as those in Ganoids and Dipnoi, but their serial homology with the ventral parts of the hæmal processes of the tail is often (*e.g.*, the Salmon) obscured by the anterior hæmal arches (*i.e.*, those in the posterior part of the trunk) being completed, not by the ribs, but by independent outgrowths of the basal parts of the hæmal processes.

In Elasmobranchii a still further divergence from the primitive arrangement is present. The ribs appear to have passed outwards, along the intermuscular septa, into the muscles; and are placed between the dorso-lateral and ventro-lateral muscles (a change of position of the ribs of the same nature is observable in Lepidosteus). This change of position, combined probably with the secondary formation of a certain number of anterior hæmal arches, similar to those in the Salmon, renders their serial homology with the ventral parts of the hæmal processes of the tail far less clear than in other types; and further proof is required before such homology can be considered as definitely established.

Under the third heading the skeletal elements supporting the fin-rays of the ventral lobe of the caudal fin of various types of fishes are compared and the following conclusions are arrived at.

(1.) The ventral lobe of the tail-fin of Pisces differs from the other unpaired fins in the fact that its fin-rays are directly supported by spinous processes of certain of the hæmal arches, instead of by indently developed interspinous bones.

(2.) The presence or absence in the tail-fin of fin-rays, supported by hæmal arches, may be used in deciding whether apparently diphycercal tail-fins are aborted or primitive.

Urogenital Organs.

With reference to the character of the adult urogenital organs, the authors show that for the female the descriptions of Müller and Hyrtl are substantially accurate, but that Hyrtl's description of the generative ducts of the male is wholly incorrect.

They find that in the male the semen is transported from the testes by means of a series (40—50) of vasa efferentia, supported by the mesorchium. In the neighbourhood of the kidney these vasa unite into a longitudinal canal, from which transverse trunks are given off, which become continuous with the uriniferous tubuli. The semen is thus transported through the kidney into the kidney-duct (segmental duct), and so to the exterior. No trace of a duct homologous with the oviduct of the female was found in the male.

With reference to the development of the excretory system, the authors have established the following points :—

(1.) That the segmental (archinephric) duct is developed as in Teleostei.

(2.) That a pronephros, resembling in the main that of Teleostei, is developed from the anterior end of the segmental duct. But they find that the pronephric chambers, each containing a glomerulus, into which the coiled pronephric tubes open, are not, as in Teleostei, completely shut off from the body cavity, but remain in communication with it by two richly ciliated canals, one on each side of the body.

(3.) The pronephros eventually undergoes atrophy.

(4.) Some of the mesonephric tubes have peritoneal funnels in the larva.

(5.) The ovarian sac continuous with the oviduct, is established by a fold of the peritoneal membrane, near the attachment of the mesovarium, uniting with the free edge of the ovarian ridge to form a canal, the inner wall of which is constituted by the ovarian ridge itself.

(6.) The posterior part of the oviduct is not formed until the ovarian sac has become developed, and had not been developed in the oldest larva (11 centims.) the authors have succeeded in obtaining.

The Alimentary Canal and its Appendages.

In this section the authors give a detailed account of the topographical anatomy of the alimentary tract in the adult. They have detected a small pancreas close to the bile-duct, and call special attention to a ventral mesentery passing from the posterior straight section of the intestine to the ventral wall of the body.

In the embryological part of the section a detailed account is given of the development (1) of the pancreas, which is described as arising as a dorsal diverticulum of the duodenum on a level with the opening of the bile-duct; (2) of the yolk sac and vitelline duct; (3) of the spiral valve, which first appears as a hollow fold in the wall of the intestine, taking a slightly spiral course, and eventually becoming converted into a simple spiral ridge.

The so-called hyoid gill, which the authors expected to find well developed in the larva, is shown not to be found even in the oldest larva the head of which was examined (26 millims.)

The last section of the paper is devoted to the consideration of the systematic position of Lepidosteus. The Teleostean affinities of Lepidosteus are brought into prominence, but it is shown that Lepidosteus is nevertheless a true Ganoid.

The arguments used in this portion of the paper do not admit of being summarised.

IV. "On a New Mineral found in the Island of Cyprus." By PAULUS F. REINSCH (Erlangen). Communicated by Professor STOKES, Sec. R.S. Received November 3, 1881.

In the western part of the Island of Cyprus I detected, during my journey in June this year, a peculiar mineral, very remarkable not only from its chemical composition but also from the large percentage of extremely well-preserved siliceous shells of microscopic Radiolaria. The locality in this not much known part of Cyprus,* is situated between the village Chynussa and the mountains running in a north-

* In the fine map of Kiepert (Berlin, 1878) this part of the island, in which the locality lies, is marked as "wooded hill country, unexplored." In all the reports of travellers through Cyprus before and after the British occupation I find no notice of this tract, which must have attracted the attention of passing travellers.

western direction, 38 miles N.W.W. in a straight line from the city of Limassol, 4 miles from the nearest point of the shores of Chrysohu Bay. The mineral is found there in enormous quantities, it covers the sides of the top of a hill about 150 meters over the lowest part of the valley beneath. One side of the hill is covered with the pure mineral, partly in a crumbled state, partly as solid rock. On some places are found compact prominent rocks of the pure mineral from 1 to 2 meters height. The locality is destitute of any vegetation. The mineral is soft and chalk-like; in a compact state it has a yellowish colour, in a powdered state an intense sulphur-like colour. The principal part of the mineral is composed of pure basic sulphate of oxide of iron, making 73 per cent.

The striking yellow coloration of the slope attracted my attention, and I thought at first sight that I had before me a large layer of a pure sort of common yellow ochre. In ravines intersecting the slope and running down to the valley, especially on the lower parts, I observed the slopes covered all over with whitish and yellowish crusts of salt from 1 to 2 inches thick. These crusts sometimes cover the soil in the ground of the valley and excavations in the slope with whitish efflorescences, 30 to 50 meters below the yellow deposit. The substance must be partly soluble, it has a peculiar taste, giving the taste of sulphate of protoxide. On all those spots which are covered with the crusts of this salt there grows no vegetation of herbs, only shrubs cover the soil. During the dry season, lasting in this part of the island from June to August, the amount of salt, crystallizing and developed from the surface of the slopes, must constantly be increasing. The upper parts of the soil more and more drying up are filled up in the dry season with the efflorescence of salt, which is previously in a dissolved state below the surface of the soil. This efflorescent salt in the lower parts of the ravines proves to be derived from the higher parts of the yellow deposit itself.

Through the influence of the rain water in the wet season (October to December) quantities of the mineral being dissolved and carried down, quantities of the solution are sucked in from the soil; later in the dry season the salt makes efflorescences on the surface if the soil is drying up. The process of efflorescence of salt in the dry season and carrying away in the wet season is repeated from year to year. The salt seems to me to be a neutral combination, and is in small amount soluble in water.

The mineral contains 1·7 per cent. hygroscopic water, and in the substance soluble in hydrochloric acid a very small amount of sulphate of alumina. The hardness is nearly 2, equal gypsum, specific gravity 1·7.

Heated to redness the mineral* turns from yellow to dark-brown

* I assign to this mineral the name of the island, and to the many names of

and at last to red-brown, the colour of oxide; it loses in average 8 to 9 per cent. sulphuric acid with combined water. When dissolved in boiling hydrochloric acid a snow-white residuum is obtained, which, under the microscope, proves to be composed of extremely well-preserved shells of microscopic Radiolaria, belonging to different genera. The size of those mostly regular globular bodies ranges between 0·045 millim. and 0·1135 millim. The quantity of this residuum amounts in a mean of three trials to 25 per cent. The quantity of soluble substance is therefore 73 per cent., if we take away 2 per cent. hygroscopic water. This soluble substance is pure sulphate of oxide of iron with a very small amount of sulphate of alumina. The quantity of the sulphuric acid in the mineral was directly determined by precipitation of the hydrochloric solution of the mineral with chloride of barium. 2,000 mgrms. of the mineral gave 1,250 mgrms. sulphate of baryta, corresponding to 431 mgrms. sulphuric acid. The amount of this acid in the mineral is therefore 21·5 per cent. The quantity of the oxide with a small amount of alumina is 51·5 per cent., corresponding to 36 per cent. metallic iron.

No traces of copper or any other metal have been found in the mineral; a trace of arsenic, however, is observed, as is shown by means of the copper-arsenic test, by boiling the hydrochloric solution with a clean copper slip, which becomes coated with a thin deposit of metallic arsenic.

Cyprusit is composed as follows:—

Oxide of iron, with a very small amount of alumina	51·5
Sulphuric acid	21·5
Insoluble siliceous substance	25
Hygroscopic water	2
	100·0

V. "On certain points in the Anatomy of Chiton." By ADAM SEDGWICK, M.A., Fellow of Trinity College, Cambridge. Communicated by F. MAITLAND BALFOUR, F.R.S. Received November 5, 1881.

An account of the structure of the kidney of Chiton has long been a want in morphology. Middendorff,* in 1848, described a branched gland lying ventrally on each side of the body cavity which he identified as kidney; but he records no observation on the structure of the

objects belonging to natural history derived from Cyprus I add a new one; the mineral would bear the name "Cyprusit."

* "Mémoires de l'Acad. de St. Pétersbourg," 6th ser., vol. vi.

gland, and expressly states that he was not able to make out its opening or relation to other organs. Schiff,* ten years later, was unable to find this gland in *Chiton piceus*, and throws doubt on Middendorff's interpretation of its function.

Von Jehring† has comparatively recently recorded some observations on the kidney of Chiton, and starts from the position that no kidney is known in Chiton, Middendorff's view as to the nature of the branched gland having been sufficiently refuted by Schiff's later observations. Von Jehring states that in the species of Chiton observed by him, the kidney consists of a branched gland lying ventral to the rectum in the hinder part of the body cavity, and that it opens by a single median pore ventral to the anus. He further figures this opening.

While staying at Herm this summer I found a fair number of a good-sized species of Chiton—*Chiton discrepans;* and the results which I have obtained from the study of the anatomy of this form, especially those which concern the kidney, seem to me sufficiently important for immediate publication. In the first place, I may mention that I have seen nothing in any of my dissections or sections which in the least supports von Jehring's statements as to the existence of a median renal duct and opening; and that my observations are entirely opposed to the conclusion arrived at by this investigator as to the unpaired nature of the kidney of Chiton. On the contrary, Middendorff's observations, so far as they went, were perfectly correct. The paired lateral branched gland described by the latter observer is part of the kidney.

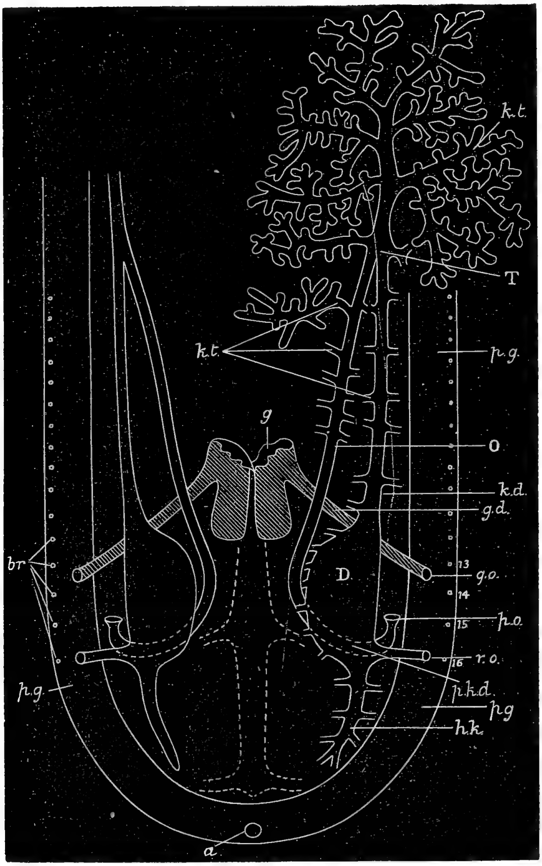
The kidney of Chiton is a paired gland with paired openings into the pallial groove and into the pericardium, and is constructed on the type always found in molluscan renal organs (fig. 1). It opens in the species I have chiefly examined (*Chiton discrepans*) into the pallial groove (fig. 1, *r.o.*) internal to, but on a level with the last gill (16). The duct runs from the opening round the outside border of the pallial nerve (fig. 2, *r.o.*), and then passes inwards to open into a bladder-like structure placed in the body cavity (fig. 1, D, and fig. 2, D). This bladder-like structure lies close to the body wall immediately beneath the pericardium (fig. 2, *p.c.*), and it does not seem to extend backwards beyond the last gill.

On a closer examination by means of sections, it is seen to be beset by a number of branched glandular cæca, lying in the hinder part of the body cavity (fig. 2, *k.t.*), which open into it, and into a backward prolongation from it (fig. 1, *h.k.*). These branched glandular cæca on opening the body cavity are seen as a mass of tubes apparently interlacing with those of the opposite side, and lying ventral to the

* Schiff, "Zeit. f. Wiss. Zool.," Bd. ix.

† "Morphol. Jahrbuch," Bd. iv.

FIG. 1.

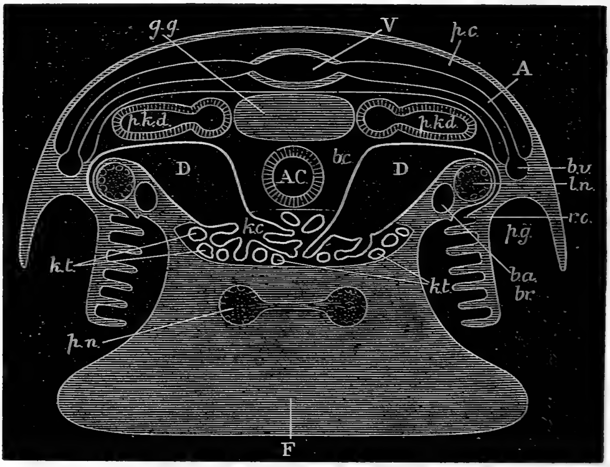


A diagrammatic representation of the kidney and generative ducts of *Chiton discrepans*, viewed from the ventral surface. The pallial groove is represented as enclosed by the lines *p.g.*; and in it are seen the 16 gills (*br.*), the generative (*g.o.*) and renal (*r.o.*) orifices; and the anus (*a.*) The branched nature of the kidney is shown in the anterior part of the figure on the right side; posteriorly these secreting tubules are omitted. On the left side of the figure the kidney duct alone is indicated.

a., anus; *br.*, branchiæ; D, dilated part of kidney duct opening to exterior: *g.* points to the junction of the generative duct with the generative gland; the generative gland is supposed to be torn away; *g.d.*, generative duct; *h.k.*, posterior part of kidney duct; *g.o.*, generative orifice; *k.t.*, secreting tubules of kidney; *k.d.*, duct of kidney running forward, bending round at T and running back, receiving glands as far back as O. From O it runs to the pericardial opening *p.o.*, receiving no glands; *p.g.*, pallial groove; 13, 14, 15, 16, last four branchiæ; the ventricle and auricular openings are indicated by dotted lines.

rectum on the floor of the body cavity (fig. 2, *k.t.*). This portion of the kidney has been seen and described by von Jehring, but instead of constituting the whole of the kidney and opening to the exterior by a median pore, it is only the posterior part, and opens on each side into the bladder-like structure which opens to the exterior in the

FIG. 2.



A diagrammatic representation of a transverse section through *Chiton discrepans* at the level of the renal orifices (*r.o.*, fig. 1). Dorsally is the pericardial cavity with the heart, separated by the pericardial floor from the general body cavity (*b.c.*), containing the viscera. Ventrally is the posterior apparently median unpaired part of the kidney (*k.t.* and *k.c.*) seen by von Jehring. A little in front of this section, the kidney tubules take up a distinctly lateral position.

D ; *p.g.* ; *b.r.* ; *k.t.* ; *r.o.* as in fig. 1.

A, auricle ; V, ventricle ; *b.v.*, branchial vein ; *b.a.*, branchial artery ; *p.c.*, pericardial cavity ; *l.n.*, lateral nerve (pallial) ; *p.n.*, pedal nerve ; F, foot ; A.C., alimentary canal ; *g.g.*, generative gland ; *b.c.*, body cavity ; *k.c.* see *k.t.* ; *p.k.d.*, part of kidney duct which in fig. 1 is hidden from view by D.

position described above. I have many series of sections through this hinder part of the kidney of Chiton, which prove most conclusively that these hinder ventrally placed tubules do open in the way I have stated.

On examining the anterior end of the bladder-like structure it is found that it is continued forwards as a duct (fig. 1, *k.d.*), which receives, all along its course, the ducts of bunches of branching glandular cæca, lying at the side of the body cavity (fig. 1, *k.t.*). These branching glandular cæca constitute the gland described by Middendorff. Their structure precisely resembles that of the first described posterior tubules, which open into the dilated part of the duct and its backward prolongation. The duct can be traced forward to about the level of the 4th shell-plate (fig. 1, T), at which point it turns sharply round and runs back parallel with the first part of its course. A considerable part of the gland lies in front of this turning point of the duct; the secretion of this part is poured into a branch given off from the main duct at the bend (fig. 1, T). The posteriorly directed part of the renal duct lies close to the dorsal edge of the part running forward, and, like the latter, receives the efferent ducts of bunches of glandular cæca (fig. 1). From the level of the 5th shell-plate (fig. 1, O) to its posterior termination (fig. 1, *p.o.*), about to be described, it receives no glandular cæca, but runs backwards as a simple duct distinguishable by its brown colour, which is due to a deposit of colouring matter in its walls. On reaching the level of the bladder-like dilatation of the kidney duct first described, it applies itself to the dorsal inner wall of that structure as far back as the level of the last gill. At this point, which marks the hind border and the external opening of the bladder, it runs outwards and then forwards (fig. 2, *p.k.d.*) in close contact with the dorsal side of the lateral nerve cord. It runs forward to about the level of the penultimate gill, where it suddenly stops and opens by a small pore into the pericardium (fig. 1, *p.o.*) beneath, *i.e.*, ventral to the anterior part of the auricle.

Comparing the arrangement of the kidney of Chiton with that of Anodon, there is seen to be a close agreement. In both the kidney is paired and consists of a gland bent on itself, opening at the one extremity into the pallial cavity, and at the other into the pericardium. In both the kidney is unsegmented (a fact to be remembered when the nature of the shell and gills of Chiton is discussed). There is a further agreement between these two animals in the relation of the openings of the generative ducts to those of the renal ducts; in both the latter are placed close behind the former.

With regard to the minute structure of the kidney of Chiton, I have no exact observations. It is necessary to study it in the fresh state. The inner borders of the cells lining the glandular cæca are stated by von Jehring to be ciliated.

The most internal part of the kidney duct, *i.e.*, that which receives no glandular cæca (fig. 1, O to *p.k.d.*), is, with the exception of a small portion adjoining the pericardial opening, lined by columnar cells containing a yellow colouring matter, which gives this portion of the duct a yellow colour, easily visible to the naked eye. This yellow colouring matter, which seems to be part of the excretion of the cells lining the duct, is absent in the part of the duct which runs forwards from the level of the hinder edge of the bladder to the pericardial opening (*p.k.d.* to *p.o.*). Here are found large columnar cells provided with long cilia, which line also the pericardial opening.

The cells of the glandular cæca seem to have the structure usually seen in molluscan renal organs, and have been correctly described by von Jehring.

To sum up, the kidney of Chiton consists of—

(1.) A duct opening to the exterior in the pallial groove behind the generative opening, and internally into the pericardium.

(2.) Glandular cæca opening into this duct.

The duct may be described as consisting of three parts:—

(1.) The part into which the glandular cæca of the kidney open. This part is open behind where it opens to the exterior (fig. 1, D). In front it bends round (fig. 1, T), and runs backwards to about the level of the 5th shell-plate, where it changes its character, and is continuous with (2) a duct (fig. 1, O) containing brown colouring matter in the columnar cells lining it, and receiving no glandular cæca. This part extends back to the level of the last gill, where it turns outwards, and becomes continuous with (3) a part running forward for a short distance close to the lateral nerve, and lined by large ciliated columnar cells. This part opens in front at the level of the penultimate gill into the pericardium (fig. 1, *p.o.*). I expected to find the communication between the two parts of the renal duct behind in the region of the bladder, and for some time I was puzzled at not finding it. On mentioning the arrangement of parts to Mr. Balfour, he suggested that the communication might possibly be found in front, reasoning from the analogy of the structure of the kidney in other Mollusca. On examining the anterior part of the gland more carefully, I at once found that his suggestion was correct, the two parts of the gland communicating as I have described. I have no observations to add to those of previous observers, on the general arrangement of the nervous system. I may mention that the lateral and pedal nerves have a coating of ganglion cells, and a central core of fibres.

The animals are diœcious. The generative gland is unpaired and dorsal. The generative ducts are paired, and are attached to the hinder border of the gland, and open in *Chiton discrepans* into the pallial groove between the 13th and 14th gill, in a line with the opening of the renal duct. The duct passes dorsal to the anterior end of the dilated part of the renal duct (fig. 1, *g.d.*); and then curls round the outer border of the lateral nerve-cord to its opening, presenting in this respect precisely the same relation as does the renal duct. The male duct has a short direct course to its opening (fig. 1); while the female duct is much coiled.

Another species, *Chiton cancellatus*, which I have examined, presents essentially the same arrangement of its renal organ and generative ducts as that just described for *Chiton discrepans*.

Dall* states that in some species of Chiton, the generative products

* "Proceedings of the United States' National Museum," vol. i.

escape into the body cavity and make their exit by several pores placed close together, and symmetrically, on each side in the pallial groove; oviducts apparently being absent. I have not any specimens of the species he mentions as possessing this peculiarity (*e.g.*, *Chiton marmoreus* and *ruber*), so have not been able to test his observations by means of sections.

I hope to be able to give a fuller account of these and other points in the anatomy of Chiton at some future period, for the preparation of which it will be necessary to obtain some fresh specimens.

VI. "The Action of Cutting Tools." By A. MALLOCK. Communicated by Lord RAYLEIGH, F.R.S. Received November 4, 1881.

The action of cutting tools has not often been treated from a theoretical point of view; in fact I only know of two papers on the subject, one by Professor Willis and the other by Mr. Babbage. Of these Professor Willis's paper is purely geometrical, showing what angles the edges of tools may make with one another if the cutting angles are to be such as experience shows to answer best. Mr. Babbage, on the other hand, does not enter at all on the question of the shape of the tool, but by making certain assumptions as to the relation between the dimension of the shaving removed by a tool and the work required to remove it, he deduces some results showing how to remove a given amount of material most economically. His conclusions cannot be considered correct, nor do they agree with experience (see Note 1). I do not attempt in the following paper to give any dynamical investigation of the action of tools, in fact it would be almost impossible to do so without a more extended knowledge of the laws which govern the strains in bodies subjected to large forces, but merely to classify the various actions which observation shows to be caused by the progress of the tool, and to quantify approximately the work expended in each. For this purpose, shavings from a great variety of substances were examined both in the course of their formation (by a microscope attached to the toolholder) and after they were removed.

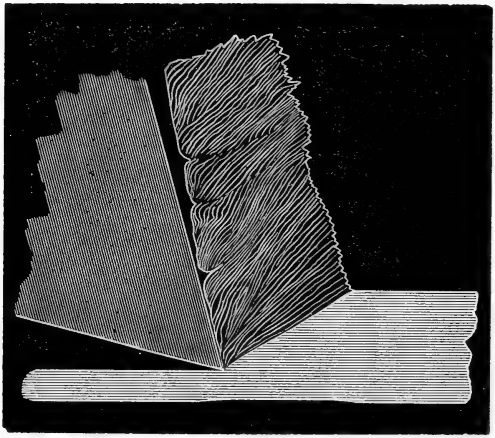
Among the substances examined may be mentioned four or five samples of wrought iron, and as many of steel, cast iron, gun metal, brass, copper, lead, zinc, hard paraffin, soap, and clay.

This last-mentioned substance was found extremely useful in examining the formation of the shavings, for by altering the amount of water it contained its behaviour under the tool could be made to resemble almost any of the others, and at the same time the forces required to take large cuts were not greater than could be conveniently applied by hand.

Sections were made of many of the metallic shavings, and the polished surfaces of these when washed with dilute nitric acid showed their internal structure very well.

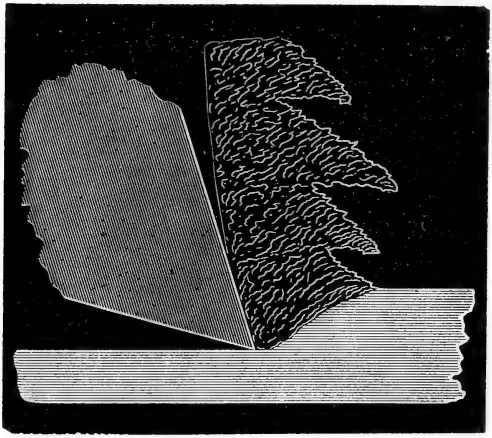
Figs. 1 to 8 show some of these sections enlarged.

Fig. 1.



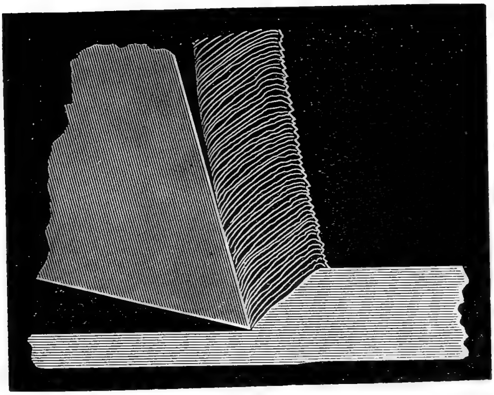
Shaving of wrought iron (armour plate). Actual thickness ·25 inch.

Fig. 2.



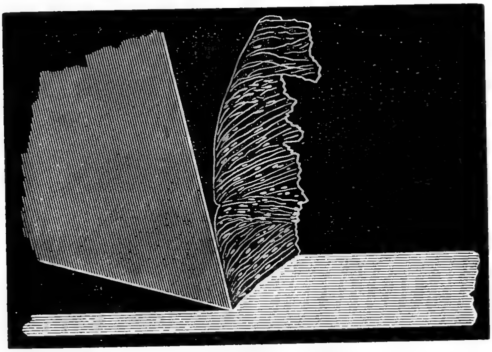
Shaving of cast iron. Actual thicknes ·1 inch.

FIG. 3.



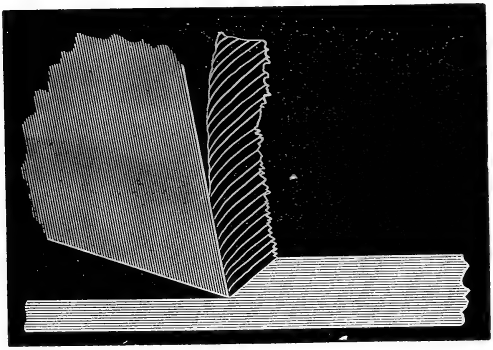
Shaving of hard steel (Whitworth). Actual thickness ·15 inch.

FIG. 4.



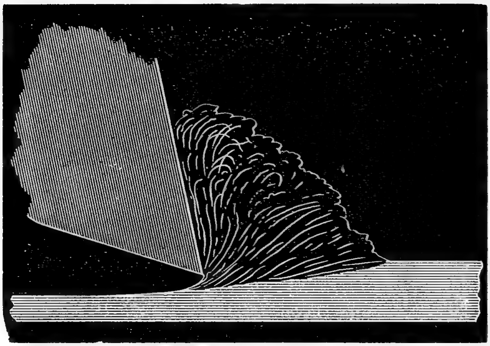
Shaving of gun metal. Actual thickness ·08 inch.

FIG. 5.



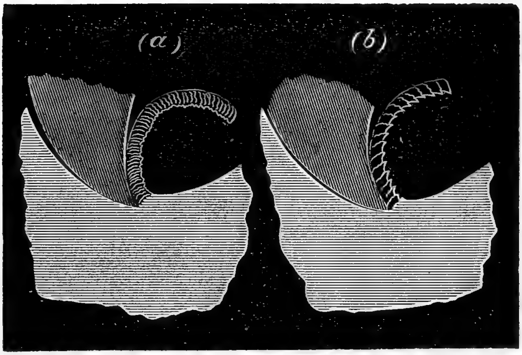
Shaving of brass. Actual thickness ·08 inch.

FIG. 6.



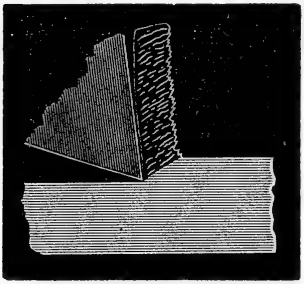
Shaving of copper (unlubricated).

FIG. 7.



(a.) Borings, steel. Actual thickness ·005 inch.
(b.) „ brass. „ „ ·01 „

FIG. 8.



Shaving of copper (lubricated with soap and water).

It will be seen that there is little difference in any of these, though the materials are of all degrees of hardness, and vary in thickness from three-eighths of an inch, the thickest iron shaving examined, to ·003.

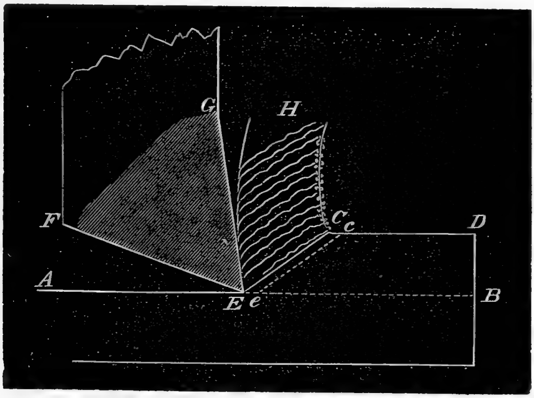
Indeed the action at the edge of the tool seems identical in all cases, such differences as there are being due to the action of the face of the tool on the shaving, while the latter is being pushed out of the way; and this action depends on some of the physical constants of the substance operated on, chiefly its coefficients of friction on the metal of the tool and on itself, but in part also on its ductility, and in some cases, as in lead, on the property which freshly formed surfaces have of reuniting under pressure.

The tools do not act, properly speaking, by cutting but by shearing, and the shaving removed by them may be accurately described as a metallic slate.

This remark does not apply to acute-edged tools, such as razors and penknives.

The difference between cutting and shearing may be defined thus: Conceive the substance to be cut to be divided into an infinite number of cubic elements by parallel planes at right angles to one another; if in a portion of this removed by a tool the elements remain cubes, the removal has been effected by pure cutting. If, however, they are only distorted but are all unaltered in volume, the removal has been effected by pure shearing; if they are both deformed and altered in volume, both cutting and shearing have been called into play.

Fig. 9.



Let ABCD be a section of the substance under the action of the tool, GEF the tool, H the shaving, CD the undisturbed surface of the substance, and AB the direction of the cut.

The advance of the tool violently distorts the material in its neighbourhood, and presently along the line *ec* the distortion becomes too great for the substance to preserve its continuity (Note 2), the lamina EC*ec* then begins to slide on *ec*, and its base E*e* to move up the face of the tool, while the point of the tool is repeating the distortion and separation on fresh material ahead.

This in all the cases I have examined is the manner in which all tools, except those with very acute angles, act.

The curvature of shavings appears to be due to the crushing of the base of the laminæ while passing over the face of the tool, thus making them thicker at that end than at the outer surface.

The effect of the friction between the laminæ and the tool has the opposite tendency of thinning out the ends of the laminæ and preventing the curvature, so that when from want of lubrication or the nature of the material the friction becomes excessive, the shavings are nearly straight.

The shaving is generally shorter than the path of the tool, which shows that BED is less than 45°.

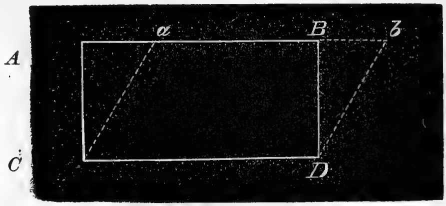
I will now attempt to take account of the forces which are brought into play by the action of the tool.

These are due to (1) elastic distortion, (2) elastic bending, (3) permanent distortion, (4) permanent bending, (5) internal friction, *i.e.*, the friction of the laminæ sliding over one another, (6) the friction of the material on the tool, and (7) if the tool is not considered as being perfectly sharp, the radius of curvature of the edge will appear in a term giving the limit to the rate of distortion in its neighbourhood.

If the tool is perfectly sharp the rate of distortion at the edge is infinite, and the material at the edge can offer no resistance to its progress unless capable of infinite distortion without rupture.

This is easily seen to be the case by the following considerations:—

Fig. 10.



Let ABCD (fig. 10) be the section of a parallelopiped of any material, and let it be distorted as shown by the dotted lines until rupture takes place. The work expended in bringing it to its distorted state depends on B*b*, *i.e.*, the distance AD must be moved before the limit of distortion is reached, and this is simply proportional to BD, the thickness of the parallelopiped; hence when BD is nothing the work is also nothing. The rate of distortion, *i.e.*, the distortion produced by a definite motion of AD, is inversely as BD, and is therefore infinite when BD=0.

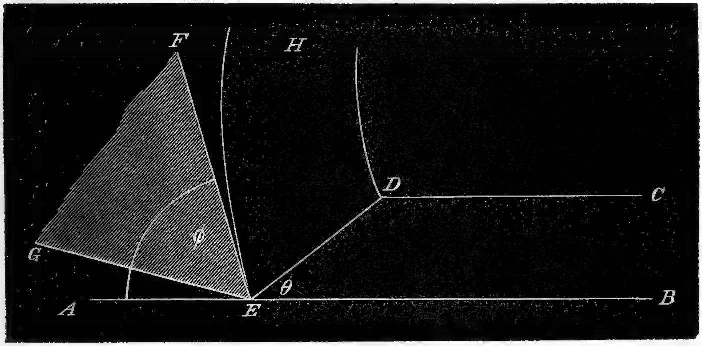
Thus, when the rate of distortion is infinite and the limit of distortion is finite, no work is required to effect the rupture.

In the case of the tool it is, of course, only actually at the edge that the rate of distortion is infinite; but if it were possible to apply suitable forces simultaneously at every point of a solid through which a surface of separation was desired to pass, that separation could be effected with no expenditure of work whatever.

The resistance due to elastic and permanent distortion is $\frac{Q}{\cos\theta}$, θ being the angle DEB (fig. 11), Q the integral of all the reaction due to distortion along the line EC at the moment sliding begins.

The work done in internal friction is EC × distance through which the lamina slides per unit travel of tool × by the pressure under which the sliding takes place × by the coefficient of friction of the material on itself.

FIG. 11.



Let t=BC, the thickness of the cut,

t'=thickness of shaving,

μ=coefficient of friction of the material on itself,

μ_1=coefficient of friction of material on the tool,

θ=DEB,

ϕ=FEA, viz., the angle which the face of the tool makes with AB,

then

$$t'=t\frac{\sin(\phi+\theta)}{\sin\theta} \quad \ldots \ldots \ldots \quad (1),$$

$$\text{ED}=\frac{t}{\sin\theta} \quad \ldots \ldots \ldots \quad (2).$$

The sliding along ED per unit advance of tool is—

$$\cos\theta + \cot(\phi+\theta)\sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

The pressure under which the sliding takes place is to the normal pressure on the face of the tool as

$$\cos(\theta+\phi) + \mu_1 \sin(\theta+\phi) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

Thus the work expended in internal friction is proportional to

$$\mu\frac{t}{\sin\theta}\{(\cos\theta+\sin\theta\cot(\phi+\theta))(\cos(\phi+\theta)+\mu_1\sin(\theta+\phi))\} \quad . \quad (5).$$

The work done in friction against the face of the tool is for the same travel proportional to

$$\mu_1 t\frac{\sin\theta}{\sin(\phi+\theta)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6).$$

Collecting these results, the total resistance will be made up as follows:—

(1.) Bluntness$=A\rho$ where ρ=radius of edge and A=constant.

(2.) Elastic and permanent distortion$=\frac{Q}{\cos\theta}$.

(3.) Internal friction$=\frac{\mu t}{\sin\theta}\{(\cos\theta+\sin\theta\cot\overline{\phi+\theta})$
$(\cos\overline{\phi+\theta}+\mu_1\sin\overline{\phi+\theta})\}$.

(4.) Friction against tool $=\mu_1\frac{t\sin\theta}{\sin\phi+\theta}$.

(5.) Elastic bending$=Bt^2$.

Considering these terms in order:—

The first ought always to be small if the tool is sharp.

Q in the second term is proportional to t, and is probably a function also of ϕ and θ, but as observation shows that θ is independent of ϕ, that is to say, that for a given material any form of tool that can be employed causes sliding to begin in the same plane, it seems likely that the reaction due to distortion should not vary much with ϕ, and that for the present purpose Q may be regarded as $t\times$ constant.

The internal friction vanishes when

$$\cos\overline{\phi+\theta} = -\mu_1\sin\overline{\phi+\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A),$$

that is, when the resultant force through the face of the tool is parallel to EC.

When this is the case, however, there is a large component tending to make the tool dig into the substance, so that the form indicated by A is not one which can be used in practice without certain precautions.

The same objection applies to making the fourth term a minimum by putting

$$\phi+\theta=90° \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (B).$$

Perhaps as good a value as any for ϕ is that which makes the resultant force through the face of the tool parallel to the direction of motion. This value is given by the equation

$$\cot\phi=\mu_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (C).$$

The values obtained for ϕ for this expression agree fairly with those in common use, or at least are quite compatible with them, considering the uncertainty of the values of μ_1 for high pressures. The elastic and permanent bending is small for such values of ϕ as can be used in tools for metals, the transverse strength of the shaving (which is some hundred times less than that of a piece of the substance of the same dimensions in its natural state) not permitting it to transmit large bending forces.

In true cutting tools, where ϕ is very small, nearly the whole force acting on the blade arises from friction under the pressure on the sides of the tool caused by the bending.

It is evident, therefore, that as ϕ passes from large values to small, the importance of the term in t^2 will continually increase.

All the sources of resistance above mentioned, except the first and last, which should be small, are proportional to the thickness of the shaving and, of course, also to its breadth.

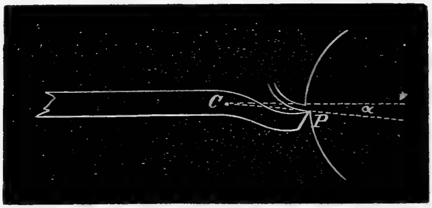
Thus to remove a given volume of material will require the same expenditure of work, whether it be effected by one thick cut or several thinner ones.

In practice, however, the constant friction of the machinery employed always make thick cuts the most economical. The construction of machines, and the character of work generally, confines within rather narrow limits the thickness of the cut which it is possible to take, for the force required must not be large enough to sensibly bend or distort the substance as a whole.

It would be a great advantage if tools could be so held or shaped that their accidental vibrations should not be sustained but extinguished by the reactions which they call into play; but to make this possible the phase of the vibration of the tool must precede that of the reaction which it causes by some time less than half the period of the tool, or, in other words, the resistance experienced by the tool must increase with its velocity. Now friction between solids being rather greater at low than at high velocities, the sliding of the shaving on the tool tends to keep up a vibration once started, and the same may be said of the forces due to the distortion of the substance, which are at a maximum just before a fresh lamina (such as $e \ldots . c$, fig. 9) begins to slide, and then suddenly drop to a minimum. It is plain also that a tool with a tendency to dig will call into play forces of a like character.

Vibrations are in some degree neutralised, and digging entirely avoided, by so shaping the shanks of tools that the centre about which they vibrate is in advance of the normal to the direction of motion through the cutting edge.

Fig. 12.



Let ρ be the distance of the centre of flexure (s) from the cutting edge (P), α the angle which the line joining the centre of flexure and edge makes with the normal, and $\delta\alpha$ the angular distance of the tool from its mean position, the thickness of the shaving removed is $t+\rho d\alpha$ $\tan\alpha$, and if τ be the period of the vibration of the tool, $\delta\alpha$ is proportional to $\sin c\tau$, or $\delta\alpha=\kappa\sin c\tau$, say, κ and c being constants; and since the pressure exerted by the shaving on the tool is proportional to its thickness, $\rho\kappa\sin c\tau\tan\alpha$ also expresses the variable part of the reaction. The effect of this variable pressure is neither to sustain nor extinguish the vibration, but to increase in effect the rigidity of the tool by a quantity proportional to $\tan\alpha$.

In tools designed for rough work α is usually small, but when the quality of the surface left by the tool is of more importance than the thickness of the shavings which it can remove, it may be largely increased with advantage.

Fig. 13.

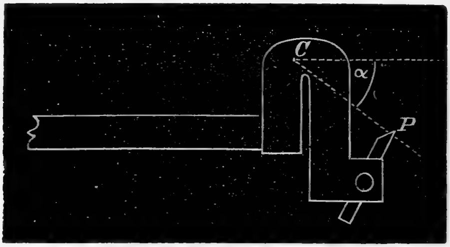


Fig. 13 shows an excellent form of cutter-holder, designed by the late W. Froude, F.R.S., in which α is about 45°. Tools held by such a cutter-holder leave a very smooth surface on the substances which they cut, and at the same time may have smaller values for ϕ given to them than when held in any other way with which I am acquainted. The general conclusion to which the foregoing remarks point are:—

(1.) Work has to be expended in dividing substances merely because the necessary forces cannot be applied locally enough; the more local the application of the force, the less is the travel, and therefore the work required to effect the separation.

(2.) All ordinary tools act by shearing the substance on which they operate in a plane inclined at an angle of less than 45° to the plane or surface swept out by the edge of the tool.

(3.) To remove a given volume of material requires nearly the same amount of work, as far as the tool itself is concerned, whether it be removed in few cuts or many; but the constant friction of the machinery always makes the thicker cuts more economical in practice.

(4.) Tools for heavy work should be so shaped that the resultant force on them may lie nearly in the direction of motion. In order that this may be the case, ϕ must be determined by equation (C).

If a less value for ϕ than this be adopted, less work will be required to effect the same cut, but the tool will have a tendency to dig.

(5.) In tools which are merely required to leave a good surface and not to take cuts of any appreciable depth, the angles are unimportant.

One curious point connected with the subject of cutting tools is the manner in which their action is facilitated by lubricants. Lubricants seem to act by lessening the friction between the face of the tool and the shaving, and the difficulty is to see how the lubricant can get there, since the only apparent way is round the edge of the tool, and there it might be expected that the contact between the tool and the substance would be too close to admit of its passage. Somehow or other, however, some of the lubricant does find its way between the shaving and the tool, and perhaps also into the substance of the shaving.

Some metals, copper for instance, when unlubricated, actually refuse to slide over the face of the tool, and the metal is then driven before the tool in a growing lump, as stiff mud would be before a board pushed through it (fig. 6). The separation in these cases does not take place at the edge of the tool, but some distance beneath it.

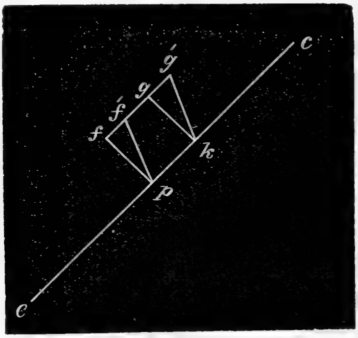
Note 1.—*On Mr. Babbage's Paper on the Principles of Tools for Turning and Planing Metal.*

Mr. Babbage, in the paper above referred to, assumes that the force required to remove a shaving of constant width may be expressed in terms of its thickness by the series $A+Bt+Ct^2+$&c., and this of course is perfectly true. But in his application he reduces this series to two terms only, viz., A and Ct^2; of these he says that A is the constant force "necessary to tear along the whole line of section each atom from the opposite one to which it was attached." Ct^2 is of course dependent on the bending and material.

As to the first of these terms, I have shown that it is $=0$ when the tool is sharp; and the second must be small, in the first place, because but little true bending occurs, and, secondly, because the resistance which a shaving can oppose to bending is, on account of its laminated structure, very feeble.

Note 2.—Though the general line of shearing is in the direction e, c, it can hardly be doubted that separation first occurs across the lines of greatest tension.

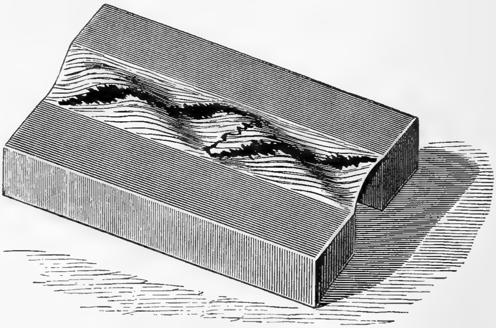
Fig. 14.



Let f, g, h, k, be a small cube of substance contiguous to ec, and unstrained; let f', g', h', k', be the same substance when strained and just about to shear. The lines of greatest tension are parallel to p, g', and rupture will take place in a direction at right angles to this.

Ruptures of this kind will happen all along the line ec, and the saw-tooth-edge left will be rubbed down when the lamina begins to slide.

Fig. 15.



Paper ruptured by distortion.

Rupture along the lines of greatest tension in shearing may be well illustrated by pasting a piece of paper over two flat boards, with straight parallel edges, about $\frac{1}{4}''$ apart; if now, preserving this distance, the boards are forced to move past one another in the direction of their edges, folds appear in the paper parallel to the lines of greatest tension, and if the sliding be continued the paper tears at right angles to the direction of the folds (fig. 15).

VII. On Seismic Experiments." By John Milne, F.G.S., and Thomas Gray, B.Sc., F.R.S.E. Communicated by A. C. Ramsay, LL.D., Director-General of the Geological Survey and of the Museum of Economic Geology. Received November 5, 1881.

(Abstract.)

This paper is an account of a series of experiments made at the Akabane Engineering Works, Tokio, for the purpose of investigating some points connected with earthquake motion. The mode of experiment consisted in creating a disturbance at a point on the earth's surface by allowing a heavy block of iron (1,710 lbs.) to fall from a height (35 feet), and observing the resulting motion produced in the earth at points variously situated relatively to the centre of disturbance. The centre of disturbance was situated near to one corner of a pond about 10 feet deep, and close to the foot of a small steep hill, the remaining ground being very nearly level, and composed of hardened mud, which extended to a depth of from 20 to 30 feet. The configuration of the ground here briefly described is clearly shown by means of a map accompanying the complete paper. In the earlier experiments a number of similar vessels of mercury were placed at the different points, and the vibrations produced on the surface taken as a rough indication of the intensity of the disturbance at the point. This method of observation showed with considerable definiteness where the motion became insensible. These preliminary experiments showed that the disturbance could be distinctly propagated to a distance of 650 feet (which was the greatest distance available); that the pond cut off the disturbance from points beyond its distant side if these points were sufficiently removed from the corner, but that the hill did not cut off the vibrations.

In subsequent experiments more definite observations were made by using seismographic apparatus, and by this means the following conclusions were reached.

A disturbance emanating from a centre as above described, produced at least two distinct sets of vibrations. One of these sets has

the direction of motion in the line joining the centre of disturbance and the point of observation, while the other set has the direction of motion at right angles to that line. The first of these is denominated the direct wave, and the second the transverse wave. The direct wave has a greater amplitude and a slightly shorter period of motion at the source, but seems to die out more rapidly than the transverse wave. The amplitude of the direct vibrations seems never to have exceeded 0·5 millim. at 50 feet, and 0·1 millim. at 250 feet from the centre. The amplitude of vibration was very nearly inversely as the distance from the source. The direct wave was completely cut off by the pond and nearly, if not completely, by the hill, but the transverse wave extended along the distant side of the pond to a considerable distance, and was little affected by the hill. When the motion of a point on the earth's surface was registered by means of a seismograph, it was found to be such as would result from the composition of two harmonic motions of different period, and in different directions. One of the most important points attended to in these experiments was the determination of the velocity of propagation for the different waves. The method finally adopted for this purpose was to mark by means of a telegraphic arrangement, simultaneously, and at definite intervals, on two smoked glass plates, placed at different distances along the same line from the source, the same instant of time. These plates were moved by clockwork, and were used for the reception of the seismograph record.

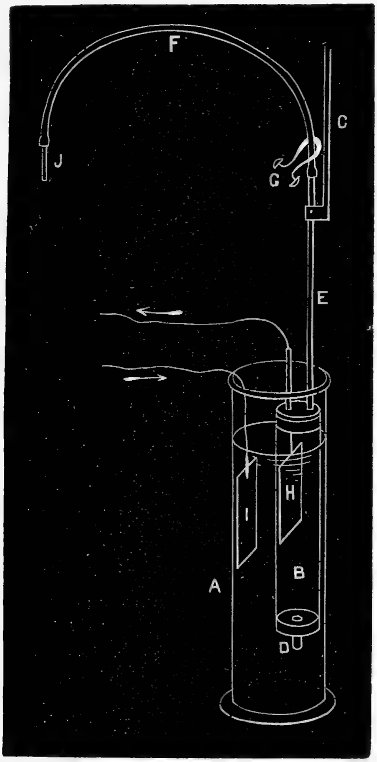
It is evident that the time-marks on the plate give the means of comparing the times of arrival of the direct, or the transverse wave, according to circumstances at the two stations, and hence, knowing the time-interval between the marks on the plates, the velocity of propagation could readily be calculated.

As the result of these observations the surprisingly low velocity of 438 feet per second for the direct, and 357 feet per second for the transverse wave, was obtained. The soft nature of the material through which the disturbance was propagated is given as the probable reason for this result.

The results of similar experiments by Mr. Robert Mallet, at the Hellgate explosions, in New York Harbour, are referred to. At the conclusion of the paper an example of the records obtained in actual earthquakes is given and briefly described.

VIII. "On the Electrolytic Diffusion of Liquids." By G. Gore, LL.D., F.R.S. Received November 8, 1881.

In a paper on the "Influence of Voltaic Currents on the Diffusion of Liquids" ("Proc. Roy. Soc.," vol. 32, 1881), I described a number of phenomena resulting from the passage of an electric current vertically through the boundary surfaces of mutual contact of two electrolytes lying upon each other. As it was not possible by means of the apparatus employed in that research to definitely ascertain whether the mass of liquid expanded or moved as a whole in the line of the current, I devised the following arrangement for the purpose of more conclusively testing that question, and to obtain additional data to assist in explaining the phenomena previously observed.



A is a glass vessel containing the heavier liquid, B is a glass tube about 15 centims. long and 2 centims. diameter, containing the lighter solution, and capable of being raised and lowered by means of the rack C and a pinion (not shown in the sketch), attached to a fixed upright support. The tube B is closed at the lower end by an india-rubber bung, in a hole in the centre of which is fixed the open glass meniscus tube D, about 16 millims. long, and having a bore of about 6 millims.; it is also closed at the top by a perforated bung, through which proceeds an open glass tube E, of somewhat smaller diameter than the meniscus tube, and about 15 centims. long. To the upper end of E is attached an india-rubber tube F, provided with a pinch-tap G. H and I are two sheet platinum electrodes, each about 7 centims. long, and 18 millims. wide, for connexion with a voltaic battery. The connecting wire of H is hermetically sealed in a glass tube, which fits air-tight into the bung.

In using this apparatus, the vessel A is shifted from its place, and the heavier liquid poured into it. The tube B is then filled by means of suction at J with the lighter liquid up to a level in E, a little above the bung. The tube F is then closed by means of the pinch-tap G, the vessel A replaced, and B, &c., lowered by means of the rack and pinion until the pressure of liquid in A just balances that in B, the difference of level being approximately determined beforehand, by taking the specific gravities of the two liquids. A definite meniscus is then easily formed in the tube D, by opening the pinch-tap and raising B until a drop of liquid issues below, and then lowering it a minute distance. It is particular that no air bubble exists in B, and in order to facilitate the escape of any, the interior of the upper bung is made of a funnel shape, and coated very smoothly with sealing wax.

In an experiment I made with this apparatus, the heavier liquid was a solution of nitrate of mercury of specific gravity 1·30, and the lighter one a solution of cupric nitrate, specific gravity 1·22. With an upward current from 18 Grove's elements in single series, a colourless horizontal line soon appeared below the meniscus in D, advanced downward, and underflowed the end of the meniscus tube. Neither the meniscus in the lower tube D, nor that in the upper one E, shifted in position during the passage of the current. These results were repeatedly verified with the meniscus at different distances, varying from one-sixteenth to one-eighth of an inch above the bottom of the tube.

Remarks.—These results show first, and most conclusively, that liquid diffused downwards continuously through the meniscus during the passage of the upward current; and second, that during the continuance of the current, either no manifest expansion occurred in the bulk of the liquid in B, and that equal volumes of liquid diffused in two opposite directions through the lower meniscus; or, that any expansion of the bulk of liquid in tube B was compensated for by downward diffusion of an equal bulk of liquid. Another possibility is that the united volumes of the metallic deposited copper, and of the acid element from which it had been separated by electrolysis, was greater than before such separation, and that this was compensated for by the volume of liquid diffused downwards through the meniscus.

IX. "On the Coefficients of Contraction and Expansion by Heat of the Iodide of Silver, AgI, the Iodide of Copper, Cu_2I_2, and of Five Alloys of these Iodides." By G. F. RODWELL, F.R.A.S., F.C.S., Science Master in Marlborough College. Communicated by Professor A. W. WILLIAMSON, For. Sec. R.S. Received November 11, 1881.

(Abstract.)

The experiments described in this paper are a continuation of those published at intervals during the last five years in the "Proceedings" in connexion with the anomalous expansion by heat of certain iodides.

Fresh and more accurate determinations of the coefficients of contraction and expansion of iodide of silver are given.

Certain physical and chemical properties of cuprous iodide are detailed, and determinations of its coefficient of expansion by heat.

Five alloys of iodide of silver with cuprous iodide were prepared, having the following composition and percentage of iodide of silver:—

Composition.		Percentage of iodide of silver.
$Cu_2I_2.AgI$	....	38·2233
$Cu_2I_2.2AgI$	....	55·3066
$Cu_2I_2.3AgI$	....	64·9884
$Cu_2I_2.4AgI$	....	71·2225
$Cu_2I_2.12AgI$	....	88·1304

The physical properties of these bodies are described, and their coefficients of contraction and expansion are determined, and the volumes between 0° C. and the melting point are deduced therefrom.

A general discussion of the results is afterwards given, in which these alloys are compared with the five chlorobromiodides of silver previously described ("Proc. Roy. Soc.," vol. 25, p. 303), and with the lead-silver iodide alloy, the properties of which were described in the last communication of the author on this subject ("Proc. Roy. Soc.," vol. 32, p. 540).

The following are some of the facts noticed in connexion with the alloys:—

1. The specific gravity varies but slightly, viz., from 5·7302 to 5·6950, and is little above the mean specific gravity of the constituents.

2. The melting points are in all cases much lower, for while the melting point of iodide of silver is 527° C., and of iodide of copper

601° C., the highest melting point of any one of the alloys is 514° C., and the lowest 493° C.

3. Some of the alloys possess three points of similar density, and some two, at different temperatures. They are resinous in fracture and transparent in thin layers. When pulverised they furnish brilliantly yellow powders, unaffected by light.

4. When heated in a current of carbonic anhydride they volatilise very slowly. Heated in dry oxygen iodine is freely evolved, and oxide of copper appears on the surface of the mass. When heated in dry hydrogen, hydriodic acid is produced, and the metal is reduced.

5. The coefficients of expansion of the alloys below the point at which contraction on heating commences, was found to decrease as the percentage of iodide of silver was augmented. Thus—

Percentage of AgI.		Coefficient of expansion.
38·2232	....	·00004998
55·3066	....	·00003750
64·9884	....	·00002307
71·2225	....	·00001998
88·1304	....	·00000636

The same fact was observed in the case of the chlorobromiodides of silver. A curve table shows results.

6. While the iodide of silver commences its considerable contraction at 142° C., the five chlorobromiodides of silver, the percentage of iodide of silver in which varies from 26·1692 to 73·9285, and the lead-silver iodide alloy, the percentage of iodide of silver in which amounts to 33·794, all commence their contraction at 124° C., that is, 18° C. lower, although the coefficients of expansion of the associated bodies necessarily differ. Thus it would appear that 124° C. is the temperature at which iodide of silver commences its passage from the crystalline into the amorphous condition, when freed from the attraction of its own molecules, provided no other attraction or influence supervenes; while the attraction exerted when it exists unalloyed with any other substance, and when its molecules are hence much nearer to each other, raises the point of commencement of the change to 142° C.

7. The probable cause of this is discussed.

8. When the same result was looked for in the case of the copper-silver iodide alloys it was not found. In fact, the presence of the iodide of copper, instead of promoting the assimilation of molecular motion, and lowering the point at which the change from the crystalline into the plastic condition commences, was found to considerably raise it, although the coefficient of expansion of the iodide of copper is lower than that of either chloride or bromide of silver, or of the iodide of lead, which enter into the composition of the other alloys.

Percentage of iodide of silver in the copper-silver iodide alloys.		Temperature at which contraction on heat commences.
38·2232	....	284° C.
55·3066	....	233
64·9884	....	214
71·2225	....	199
88·1304	....	153

Thus while 66·206 per cent. of iodide of lead lowered the point of change 18° C., the presence of 61·7767 per cent. of iodide of copper raised it 142° C.

9. The possible causes of these results are discussed.

10. The lead-silver iodide alloy is compared with the copper-silver iodide alloy, as to structure, properties, &c.

11. The results of the microscopic examinations of these alloys is given, and shown by drawings.

12. The special properties of each alloy are described.

Erratum.—"Proc. Roy. Soc.," vol. 32, p. 550, 16 lines from bottom of page: for "more than twenty times," read "*nearly four times.*"

X. "On the Vibrations of a Vortex Ring, and the Action of Two Vortex Rings upon each other." By J. J. Thomson, B.A., Fellow of Trinity College, Cambridge. Communicated by Lord Rayleigh, F.R.S. Received November 16, 1881.

(Abstract.)

In the first part of the paper it is shown that if the circular axis of a vortex ring be displaced so as to be represented by the equations—

$$\rho = a + \alpha_n \cos nd,$$
$$z = \beta_u \cos nd.$$

when ρ is the distance of a point on the circular axis from the straight axis, and z the distance of a point on the circular axis from its mean plane, then—

$$\alpha_n = \mathrm{A} \cos\left(\frac{\omega e^2}{2a^2} \log \frac{2a}{e} n\sqrt{n^2-1}\,.\,t + \mathrm{B}\right),$$

$$\beta_n = \mathrm{A}\,\frac{\sqrt{n^2-1}}{n} \sin\left(\frac{\omega e^2}{2a^2} \log \frac{2a}{e} n\sqrt{n^2-1}\,.\,t + \mathrm{B}\right),$$

when ω is the angular velocity of molecular rotation, e the radius of the cross section of the vortex core, and a the radius of the aper-

ture. The cross section is supposed small compared with the aperture, so that e is small compared with a.

Thus the time of vibration is—

$$2\pi/\frac{we^2}{2a^2}\log\frac{2a}{e}n\sqrt{n^2-1},$$

and the motion is stable for all such displacements.

In the second part of the paper the action of two vortices, which move so as never to approach nearer than a large multiple of the diameter of either, upon each other, is considered, and the following results among others obtained :—

If ϵ be the angle between the direction of motion of the vortices, c the minimum distance between their centres, v the velocity of translation of vortex (i), w that of vortex (ii) ; α and β angles given by—

$$w\cos\alpha=v\cos\beta,$$

$$\alpha+\beta=\epsilon.$$

m and m' the strength of vortices (i) and (ii) respectively, a and b their radii ; k the relative velocity of the vortices, viz., $\sqrt{v^2+w^2-2vw\cos\epsilon}$; then, in the standard case when the vortices are moving in the same direction and (I) first passes through the points of intersection of their directions of motion, we have the following results :—

The direction of motion of I is deflected towards the direction of motion of II through an angle whose circular measure is—

$$\frac{m'b^2a\cos\alpha\sin 2\beta}{kc^3}.$$

The direction of motion of II is deflected in the same direction through an angle—

$$\frac{ma^2b\cos\beta\sin 2\alpha}{kc^3}.$$

The radius of vortex (i) is increased by—

$$\frac{m'b^2a\cos\alpha(1+\cos 2\beta)}{kc^3}.$$

The radius of vortex (ii) is diminished by—

$$\frac{ma^2b\cos\beta(1+\cos 2\alpha)}{kc^3}.$$

The effects for all circumstances of motion, whether the vortices are moving in the same or opposite directions, may be summed up in the following rule :—

The vortex which first passes through the point of intersection of the direction of motion of the vortices is deflected towards the direction of motion of the other, it increases in radius and energy, and its velocity of translation is diminished; the other vortex is deflected in the same direction, it diminishes in radius and energy, and its velocity of translation is increased.

XI. Letter addressed to the Secretary R.S. by Dr. W. Roberts, F.R.S. Received December 1, 1881.

In deference to the request of Mr. W. R. Dunstan, I wish to correct an error of omission in my paper "On the Estimation of the Amylolytic and Proteolytic Activity of Pancreatic Extracts," printed in "Proc. Roy. Soc.," vol. 32, p. 145.

Mr. Dunstan points out to me that I had overlooked a paper by himself and Mr. A. F. Dimmock on the "Estimation of Diastase," published in the "Pharmaceutical Journal" for March 8th, 1879, wherein he described a process, in which (as in my method) the cessation of the iodine reaction is utilised for the purpose of gauging the activity of diastasic solutions on starch gelatine.

I had not previously seen this paper, and am now glad to have the opportunity of referring to it those who are interested in diastasimetry.

December 15, 1881.

THE PRESIDENT (followed by THE FOREIGN SECRETARY) in the Chair.

The Right Hon. Sir William Vernon Harcourt, whose certificate had been suspended as required by the Statutes, was balloted for and elected a Fellow of the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following letter addressed to the President of the Royal Society was read :—

Institut de France, Paris, 5th of December, 1881.

MY DEAR MR. PRESIDENT,—In the meeting of the Academy of to-day M. Dumas has read a letter from Professor Williamson, informing the Academy that the Copley Medal has been awarded to me. I know well and appreciate highly the value of that reward, and I beg you to offer to the Royal Society my sincere thanks.

That illustrious body honoured me, seventeen years ago, by electing me as one of its foreign members, and now has been pleased to crown my far advanced scientific career.

I beg leave to give to my English colleagues a proof of my respectful regard by presenting to them the first results of new researches on the synthesis of oxygenated bases. By the reaction of glycol-chlorhydrine on collidine and on quinoline I have obtained new alkaloids, which present a close connexion with neurine. Very soon I intend to send over to Professor Williamson a paper on that subject.

I am, with the highest regards,

Sincerely yours,

AD. WURTZ,

President of the Académie des Sciences.

The following Papers were read :—

I. "On the Electromotive Properties of the Leaf of Dionæa in the Excited and Unexcited States." By J. BURDON SANDERSON, M.D., F.R.S., &c. Received October 27, 1881.

(Abstract.)

The paper consists of five parts. Part I is occupied by the examination of two experimental researches, relating to the subject, which

have been published in Germany since the date of the author's first communication to the Royal Society in 1873,* namely, that of Professor Munk on Dionæa, and of Dr. Kunkel on electromotive action in the living organs of plants. According to Dr. Munk, the electric properties of the leaf may be explained on the theory that each cylindrical cell of its parenchyma is an electromotor, of which the middle is, in the unexcited state, negative to the ends, and that on excitation the electromotive forces of the cells of the upper layer undergo diminution, those of the lower layer an increase. He accounts for the diphasic character of the electrical disturbance which follows mechanical excitation by attributing it to the opposite electromotive reactions of the two layers of cells. According to this theory, the cells resemble in their properties the "electromotive muscle-molecules" ("Untersuchungen," vol. i, p. 682, 1848, of du Bois Reymond) differing from them in so far that their poles are positive instead of being negative to their equatorial zones. Professor Munk has constructed a schematic leaf in which the cells are represented by zinc cylinders with copper zones. A schema so made is said by him to have the electromotive properties of the unexcited leaf.

Dr. Kunkel's experiments have for their purpose to show that all the electromotive phenomena of plants may be explained as consequences of the movement of water in the organs at the surfaces of which they manifest themselves.

Part II contains a description of the apparatus and methods used in the present investigation.

In Part III are given the experimental results relating to the electromotive properties in the unexcited state, a subject of which the discussion was deferred in the paper communicated by the author (with Mr. Page) in 1876.† The fundamental fact relating to the distribution of electrical tension on the surface of the leaf when in the unexcited state is found to be that (whatever may be the previous electrical relation between the two surfaces) the upper surface becomes after one or two excitations negative to the under, and remains so for some time. This difference of potential between the two surfaces the author calls the "cross difference." It is shown that, under the conditions stated, its occurrence is constant, and that the differences of potential which present themselves when other points of the surface of the leaf are compared, may be explained as derived from, or dependent on, this fundamental difference.

Part IV relates to the immediate electrical results of excitation, *i.e.*, to the electrical phenomena of the excitatory process. In investigating these the author takes as the point of departure, an experiment which includes and serves to explain those obtained by other methods, and

* "Proceedings," vol. 21, p. 495.

† "Proceedings," vol. 25, p. 411.

is therefore termed the "fundamental experiment." It consists in measuring the successive differences of potential (cross differences) which present themselves between two opposite points on the upper and on the under surface of one lobe of the leaf, during periods which precede, include, and follow the moment at which the opposite lobe is mechanically or electrically excited. In this experiment it is found that, provided that the conditions are favourable to the vigour of the leaf, the variations of the cross difference (called the excitatory variation) occur in the following order:—

Before excitation (particularly if the leaf has been previously excited).	*Upper* surface negative to under.
At the moment of excitation.	Sudden negativity of *under* surface, attaining its maximum in about half a second, when the difference amounts to not less than $\frac{1}{15}$ Daniell.
After excitation.	Rapidly increasing negativity of the *upper* surface, beginning about 1·5″ and culminating about 3″ after excitation, and slowly subsiding.

This subsidence is not complete, for, as has been said, the lasting difference between the two surfaces is augmented—the upper surface becoming more negative after each excitation ("after-effect").

When by a similar method two points are taken for comparison on opposite lobes, the phenomena are more complicated, but admit of being explained as resulting from the more simple case above stated, in which only a few strata of cells are interposed between the leading off electrodes.

In Part V the relation of the leaf to different modes of excitation is investigated. As regards electrical excitation the results are as follows:—If a voltaic current is led across one lobe by non-polarisable electrodes applied to opposite surfaces (the other lobe being led off as in the fundamental experiment) a response (excitatory variation) occurs at the moment that the current is closed, provided that the strength of the current is adequate, and not much more than adequate. No response occurs at breaking the current. When a current of more than adequate strength is used, and its direction is downwards, the response at closing is followed by several others. This effect does not happen when the current is directed upwards. To evoke a response a current must be much stronger if directed upwards than if directed downwards through the same electrodes. Weak currents cease to act when their duration is reduced to $\frac{1}{100}''$; for stronger ones the limit is shorter. Inadequate currents, if directed downwards, produce negativity of the upper surface, which lasts for several seconds after the current is broken. This effect is limited to the surfaces through which the current is led. Its direction shows it is not dependent on polarisation. By opening induction currents, if their strength does not much exceed the limit of adequacy, a leaf may be excited at intervals for several hours without failure. Weaker currents are more effectual when directed downwards than when directed upwards. If two inadequate induction currents follow one another at any interval less than $0''\cdot4$ and greater than $0''\cdot02$, they may evoke a response. In this case a response follows the second excitation. When a leaf is subjected to a series of induction currents at short intervals ($\frac{1}{20}''$) the response occurs after a greater or less number of excitations. If the temperature is gradually diminished, the number is increased by each diminution. All of the above statements relating to excitability refer to plants kept in a moist atmosphere at 32—35° C.

From the preceding facts, and others which are stated in the paper, the author infers (1) that the "cross difference" is the expression of electromotive forces which have their seat in the living protoplasm of the parenchyma cells, and that it is due to the contact of cells in different states of physiological activity; (2) that the second phase of the excitatory variation is probably dependent on the diminution of turgor of the excited cells, and therefore on the migration of liquid; (3) but that no such explanation can possibly be accepted of the phenomena of the first phase, the time relations of which, particularly its sudden accession and rapid propagation, show it to be the analogue of the "negative variation" or "action current" of animal physiology.

II. "On some Effects of Transmitting Electric Currents through Magnetised Electrolytes." By Dr. G. Gore, F.R.S. Received November 29, 1881.

(Abstract.)

This communication treats of a class of electro-magnetic rotations observed and examined by the author. The rotations are produced in liquids by means of axial electric currents, either in the interior of vertical magnets, electro or permanent, or near the poles of such magnets, and differ from rotations previously produced in liquids placed in those positions, by the absence of radial currents, to the

influence of which rotations in the interior of hollow magnets have hitherto been ascribed.*

It is here shown that a column of an electrolyte placed under similar conditions to an iron wire or rod, when subjected to electro-magnetic torsion (*i.e.*, enclosed by an electro-magnetic helix, and traversed axially by an electric current), is twisted in a similar manner to the wire or bar. This effect, however, in the case of a liquid is not limited to paramagnetic substances, nor is the direction of torsion altered by the magnetic character of the liquid.

The rotations produced in liquids by means of axial currents are opposite in direction at the two ends of the voltaic helix, are strongest at the poles, and at a little distance beyond them, and null at the centre of the tube; they may be produced at a distance of several inches beyond the poles. The directions of rotation within the tube, and to a short distance beyond the poles, are in the case of an electro or permanent magnet opposite to those produced by a voltaic selenoid. A magnet tube, therefore, has three points of no rotation with an axial current, viz., one at its centre, and one near each end, whilst a selenoid has only the former one. The existence of the outer neutral points produced by a magnet depends upon the position of the latter to the liquid, and the distances of those points from the poles of the magnet are affected by various circumstances, which are described in the communication. If the magnet is wholly above or below the portion of liquid traversed by the axial current, the outer neutral points do not occur.

By the influence of a vertical current, the liquid as a whole may be made to rotate in either single direction; the motion at one end of the column, therefore, is not dependent upon the opposite direction of motion at the other, and torsion is not a necessary form of the effect. The reaction of the liquid in the production of the rotation is neither upon another portion of the liquid, nor upon the electrodes, nor upon the walls of the containing vessel, but upon the adjacent magnetised body, and the rotation of the liquid is confined to the portion traversed by the vertical current.

Under suitable conditions, the phenomenon of rotation is definite, conspicuous, and strong, and is usually more powerful with a tubular electro-magnet than with a voltaic coil alone. A very thin iron tube weakens the effect of the coil, whilst a thick one reverses the motion and makes it stronger. The system of rotations, either with a coil or magnet, is also perfectly symmetrical. The directions of rotation produced by a coil alone are independent of the magnetic nature of the wire of the coil. Like other electro-magnetic effects, the rotations are not prevented by the interposition of metallic screens, provided

* In the full paper it is stated that "The whole of the results may be explained by the well-known principles of electro-magnetism."

they are non-magnetic. The rotations may be easily produced by the aid of a current from three or four Groves elements, especially if permanent bar-magnets are used instead of a voltaic coil. The rotations by means of vertical currents in the liquid may be produced by the influence of coils or magnets, either above or below the liquids, as well as around it; with magnets, however, in the former positions, no external reversal points occur. A magnet placed entirely above or below the liquid produces the same direction of rotation as a coil placed either above, below, or around it. The direction of rotation produced in a liquid above or within a coil by an *upward* current in the liquid agrees with that produced by a *radial centripetal* one within the coil.

A rotation apparatus of the same kind, interposed as a screen, does not prevent or appear to affect the movements.

Each electrode may be made to separately revolve in the presence of a coil or magnet by the well-known influence of the radial currents in them; and the directions of rotation are the same with a tubular magnet as with a coil. In this respect the motion produced by radial currents differs from that produced by axial ones. With each electrode diverging currents within the coil or magnet produce dextro, and converging ones lævo, rotation when the north pole is above. The rotation of the electrodes by means of radial currents appears to be independent of that produced in the liquid by means of axial ones.

The rotation also of the vessel containing the liquid may be obtained independently of that of the electrodes, by means of the vertical current in the liquid, without the aid of the radial currents in the electrodes.

The rotations produced by a vertical axis current are not confined to liquids, but may also be produced in a solid conductor, and probably, therefore, with any body conveying an electric current or discharge.

If we regard a coil as a collection of currents, with a vertical current proceeding upwards or downwards from the centre of the coil, either on its inside or outside, the flow of the liquid is in the same direction as the current in the coil; and similarly with a vertical current proceeding in like manner from the central parts of a tubular iron or steel magnet, the flow of liquid is in the same direction as that of the nearest layer of hypothetical electric currents in the iron.

The directions of rotation produced in liquids by means of radial currents inside a magnet or coil are the same as in the solid electrodes, and are lævo at all positions with centripetal currents, and dextro with centrifugal ones, when the north pole is above. A given direction of radial current, whether in the electrodes or electrolytes, or above or below a given pole, provided that the pole was not reversed in position, produced the same direction of rotation. The direction of rotation produced by a radial current approaching a vertical coil or magnet from the outside is the same as that produced by such a current approaching it from the inside.

Various other phenomena, such as temporary reversals of the direction of rotation, successive action of the coil and iron tube, &c., &c., are recorded in the paper.

With a Selenoid.—An axial current flowing upwards from a south to a north seeking pole, produces dextro rotation at the former and lævo rotation at the latter.

With a Tubular Magnet.—These two directions are reversed at all distances between the two neutral points near the poles of the magnets, but not beyond. The phenomena, therefore, of rotation are more complex with a tubular magnet than with a selenoid. The directions of rotation produced by a vertical current outside a vertical coil or magnet are the same as those produced by it inside a coil alone.

The reversals of direction of rotation near the poles, which occur when a tubular magnet is employed, appear to be due to the inner surface of the magnet, and to the position of that surface in relation to the vertical current in the liquid. The direction of rotation and the points of reversal appear to be all independent of each other.

The action of radial currents is more simple than that of axial ones, especially near the poles of a magnet. With radial currents, either in the liquid or electrodes, there is no reversal, either at the centre of the magnet or coil, or at the poles or beyond them, or near the outside of the coil or magnet.

The experiments show the entire group of rotations produced inside and outside a vertical coil (with and without an iron core), and near its poles, by radial currents; also the group of rotations produced by vertical currents inside and outside a vertical coil and near its poles, and also those produced inside and outside and near the poles of a vertical coil with a tubular iron core, by such currents.

The experiments show in a conspicuous manner the difference of property of the interior surface of a hollow magnet and of that of a voltaic selenoid having the same kind of poles at their corresponding ends. This difference of property is well known, but is illustrated in the paper in a new way experimentally.

III. "Preliminary Report to the Solar Physics Committee on the Sun-spot Observations made at Kensington." By J. N. Lockyer. Communicated to the Royal Society at the request of the Solar Physics Committee. Received November 29, 1881.

Since the commencement of the observations, in November, 1879, of the twelve most widened lines in sun-spots, about 220 observations have been made; the maps for the first and second hundred observations have been drawn up and the tabulation of the first hundred completed. The reductions are being carried on, and I hope shortly to be able to lay a full report upon the 200 observations before the Committee, but desire, in the mean time, to bring the present preliminary one before it.

The reduction of the first hundred observations, extending from November, 1879, to September, 1880, has yielded the following results:—

1. An immense variation, from spot to spot, is to be observed between the most widened lines seen in the first hundred observations. Change of quantity or density will not account for this variation. To investigate this point I had the individual observations of lines seen in the spectrum of iron plotted out on strips of paper, and I then tried to arrange them in order, but I could not succeed, for even when the observations were divided into six groups about half of them were left outstanding.

2. If we consider the lines of any one substance, there is as much inversion between these lines as between the lines of any two metals. By the term inversion I mean of any three lines A, B, C, that we may get A and B without C, A and C without B, B and C without A, and so on.

3. We have reason to believe, from experiments made here, that most of the lines seen in the spectrum of iron volatilised in the oxy-hydrogen blowpipe flame are amongst the most widened lines.

4. Certain lines of iron have been seen at rest, while other adjacent lines seen in the spectrum of this metal in the same field of view have shown change of wave-length.

5. The spectrum of iron in the solar spectrum is more like that of the arc than that of the spark.

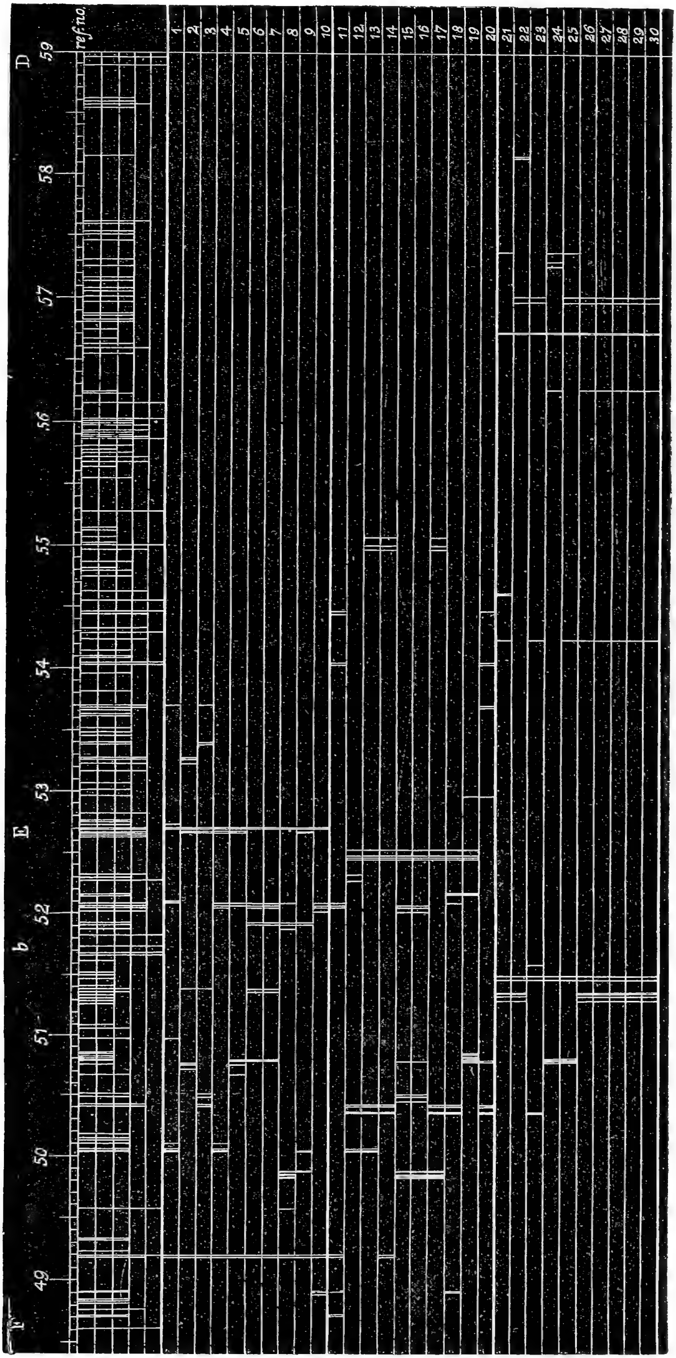
6. The greater part of the lines seen in spots and flames are common to two or more substances with the dispersion employed.

7. The first hundred spot observations being compared with a hundred observations of the spectra of flames, made by Tacchini at Palermo, have shown that there is no iron line in the region b-F common to spots and prominences.

In addition to these facts, already communicated to the Committee in more or less detail at different times, the following have been noticed in the continuation of the reductions.

8. The lines of iron, cobalt, chromium, manganese, titanium, calcium, and nickel seen in the spectra of spots and flames are usually coincident with lines in the spectra of other metals, with the dispersion employed, whilst the lines of tungsten, copper, and zinc seen in spots and storms are not coincident with lines in other spectra.

9. The lines of iron, manganese, zinc, and titanium most frequently



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seen in spots are different from those most frequently seen in flames, whilst in cobalt, chromium, and calcium the lines seen in spots are the same as those seen in flames.

10. Towards the end of the first series a few lines appeared among the most widened ones which are not represented, so far as is known, among the lines seen in the spectra of terrestrial elements. This change took place when there was a marked increase in the solar activity.

So much for the results from the first series of observations.

The second series began on 29th September, 1880, and comes down to October, 1881. From a partial reduction of the observations the following results have been obtained :—

11. The number of new lines seen amongst the most widened lines has been steadily increasing. Many of these lines are very faint in the solar spectrum, and are unrecorded by Ångström, while they are wide and dark in the spot-spectrum.

12. In the months of May and June of this year (1881), there was a great change in the spectra of the spots, the old lines dying out and new lines appearing.

13. When series of observations, consisting of ten consecutive observations of the spectra of spots, taken from the commencement of the first series in November, 1879, and from the end of it on 27th September, 1880, were compared with those made towards the end of the second series on 18th July, 1881, it was found that the lines widened in each set were markedly distinct from those in the other sets.

To illustrate this, I have prepared the diagram opposite. At the top are some of the principal Fraunhoferic lines in the region F to D, the lengths representing the intensities. The lower part of the diagram is divided into three sections by strong lines; the first of these (1—10) contains the observations made between November 12, 1879, and January 20, 1880, the second (11—20) the observations made between September 27 and October 1, 1880, and the third those made between July 18 and July 29, 1881.*

* The dates of the observations and the Greenwich numberings are as follows :—

No.	Date.	Greenwich No.
1	November 12, 1879	..
2	„ 13, „	..
3	„ 14, „	..
4	„ 27, „	..
5	„ 28, „	..
6	January 3, 1880	..
7	„ 12, „	301
8	„ 19, „	306
9	„ 19, „	306

14. At the commencement of October, 1881, there was a change in the spectra of the spots similar to that which took place in May and June, but much more abrupt, for only one of the old lines remained. This is exactly analogous to the variations Tacchini saw in the spectra of the prominences in the region F to b, in December, 1872.

15. In the first series of observations the total number of most widened lines in the region F to b was fifty-seven, forty of which were due to iron, whilst in the second series the total number of lines seen was 104, and the iron lines faded away gradually, the last disappearing on 26th July, 1881.

16. So far as the observations have gone there has been no difference caused by the nearness of the spot to the limb.

17. At the present time more than 75 per cent. of the most widened lines are not represented in the spectra of terrestrial elements.

18. A line of titanium at wave-length 5865·0 and a line of barium at wave-length 5852·5 are amongst the recent most widened lines. Both these are long lines in the spectra of these metals. The line at wave-length 5852·5 has been seen by Young in flames, with a frequency of eight.

No.	Date.	Greenwich No.
10	January 20, 1880	306
11	September 27, „	367
12	„ 29, „	367
13	„ 29, „	368
14	„ 29, „	370
15	„ 30, „	367
16	„ 30, „	368
17	„ 30, „	370
18	October 1, „	367
19	„ 1, „	368
20	„ 1, „	370
21	July 18, 1881	..
22	„ 18, „	521
23	„ 21, „	521
24	„ 26, „	525
25	„ 26, „	529
26	„ 26, „	522
27	„ 28, „	529
28	„ 28, „	525
29	„ 28, „	527
30	„ 29, „	529

IV. "On β-Lutidine." By C. Greville Williams, F.R.S.

Received November 30, 1881.

In the "Bulletin of the Chemical Society of Paris" for June 5, 1880 there appears a notice of a paper read before the Russian Chemical Society, by MM. Boutlerow and Wischnegradsky, in which they state, among other things, that by the action of alkalies on cinchonine they had obtained quinoline (chinoline) almost pure, and a volatile colourless liquid alkaloid boiling constantly at 166°, having the formula C^7H^9N; and which they say appears to be identical with the base obtained by me in distilling cinchonine with potash, and also with the lutidine of Anderson. Of the identity of the base obtained by them with β-lutidine there can be no doubt; the boiling point (166°) given by them being to half a degree the mean of the range (163° to 168°) given by me in my "Researches on Isomeric Alkaloids."*

With regard to the identity which they assume between lutidine and β-lutidine, it is evident that they have not seen my paper last quoted, or they would hardly have ignored the mass of facts which I have adduced to prove the isomerism, and not identity of the two bases.

In the "Bulletin of the Chemical Society" of Paris, Nos. 5 and 9, for September 5, 1880, p. 210, M. W. Oechsner de Coninck publishes an investigation on the lutidine, collidine, and parvoline obtained as above from cinchonine; his only reference to my work being to the "Ann. Chim. Phys.," xlv, p. 488,† in which he says that I have shown the presence of a base possessing the composition of lutidine. He then proceeds to give analyses, density, and vapour-densities of β-lutidine, apparently unaware that they were simply repetitions of what I had done many years before. I gave the analysis of the base and the platinum salt in the "Trans. Roy. Soc. Edin.," previously quoted. I also gave the analyses of the platinum salt of collidine in the same paper. The specific gravity of β-lutidine at 0° was given by me in my "Researches on Isomeric Alkaloids" as 0·9555; M. de Coninck makes it 0·95035 at the same temperature. M. de Coninck gives the vapour-density as determined in Von Meyer's apparatus as 3·80; I gave it as 3·65 in two experiments exactly agreeing with each other, and also made in Von Meyer's apparatus.‡ The formula C^7H^9N requires 3·699. In my paper "On Isomeric Alkaloids" I gave as the result of a determination by Dumas' method 3·787. M. de Coninck also states as a new result that the platinochloride of the lutidine

* "Proc. Roy. Soc.," vol. 13, p. 305, June, 1864.

† This is a *précis* of my paper, "On the Volatile Bases produced by Destructive Distillation of Cinchonine," "Trans. Roy. Soc. Edinburgh," xxi, part ii, April, 1855.

‡ "Chemical News," March 14, 1879.

from cinchonine is modified by hot water, losing two molecules of hydrochloric acid. The extraordinary difference between the decomposability of the platinum salts of lutidine and β-lutidine on boiling with water with evolution of hydrochloric acid, was one of the numerous illustrations of the isomerism of the two bases which I adduced in my "Researches on Isomeric Alkaloids" seventeen years ago. The tone of M. de Coninck's paper shows that he believes his results to be entirely new. I mention the above facts partly because they *are* facts, but, chiefly as showing that other chemists are working on β-lutidine, and that it therefore becomes necessary to publish my more recent experiments somewhat earlier than I should otherwise have done.

The preparation of β-lutidine in a state of purity is a work of much labour. On distilling cinchonine with hydrate of potassium a mixture of at least ten alkaloids is obtained, and the β-lutidine has to be separated by fractional distillation. I have, however, prepared for the purposes of this investigation probably the largest quantity of the base that has yet been obtained—rather more than half a pint.

Action of Sodium upon β-Lutidine.

I found that by the action of sodium upon chinoline it became polymerised with the formation of a body having the composition of dichinoline. This substance forms a crystalline hydrochlorate, having, when freshly prepared, a magnificent scarlet colour.* The hydrochlorate of dichinoline dyes silk a brilliant but fugitive orange colour. This reaction, namely, the formation of a coloured hydrochlorate from a colourless oily base, being probably unique, it became desirable to ascertain how β-lutidine would behave under similar circumstances.

Fragments of sodium were added to β-lutidine in the cold; they acquired a brilliant yellow colour, and had exactly the appearance of pieces of metallic gold. The mixture was then warmed until the sodium melted, it was then removed from the lamp. A violent reaction ensued, and the whole turned greenish-black by reflected light, and yellowish-brown by transmitted light. The product was left until the next day, and was then boiled for five minutes; it thickened, and, on being poured into water, yielded a heavy brown oil. No pyrrol was formed. Excess of hydrochloric acid being added, the oil dissolved, forming a brown solution; this was fractionally precipitated with solution of platinic chloride. Six precipitates were obtained; the first was pale brown, the second fawn-coloured, the third a paler fawn, the fourth Naples yellow, the fifth sulphur-yellow. The last only was distinctly crystalline under the lens. If put in a wet state into the water-oven they melt, but, if first dried over

* "Chemical News," March 1, 1878; "Proc. Roy. Soc.," vol. 31, p. 536.

sulphuric acid, the desiccation may be completed without fusion. The platinum was determined separately in the first four precipitates; the fifth and sixth were so small in quantity that they had to be mixed.

Number of precipitate.	Percentage of platinum.
I	25·28
II	24·82
III	26·40
IV	27·57
V and VI	30·28

The second precipitate, in its percentage of platinum, agrees with the formula for the platinum salt of the hydrochlorate of dibetalutidine containing two molecules of dibetalutidine, the formula being—

$$2(C^{14}H^{18}N^{2})HCl.PtCl^{4},$$

or, of a still higher polymer, in which case the formula becomes—

$$C^{28}H^{36}N^{4}.HCl.PtCl^{4};$$

whichever formula we adopt, the percentage of platinum required is 24·61, which agrees closely with the experimental number. The other precipitates were probably mixtures of this salt with the platinum salt of dibetalutidine—

$$C^{14}H^{18}N^{2}.HCl.PtCl^{4},$$

which requires 33·53 per cent. of platinum.

A second preparation was then made, but the oil obtained on treating the crude product with water was distilled; the boiling point varied from 180° C. to a temperature above the range of the mercurial thermometer. Four fractions were received, the fourth, which distilled at and above 300°, was dissolved in hydrochloric acid, and fractionally precipitated with platinic chloride.

Number of precipitate.	Percentage of platinum.
I	Lost.
II	24·69
III	26·48
IV	29·60

The second precipitate, therefore, afforded almost exactly the numbers required for the salt $C^{28}H^{36}N^{4}.HCl.PtCl^{4}$, and the others were probably mixtures of the kind I have indicated above. It is possible that the fourth precipitate had the composition shown by the formula $C^{14}H^{18}N^{2}.3HCl.PtCl^{4}$, which would require 29·84 per cent. of platinum; I propose to settle this question by further experiments.

During the precipitation of the platinum salts from the distilled base the solution became of a brilliant but fugitive scarlet colour. It is evident from the above numbers that the oil of high boiling point had the same general character as the crude mixture first examined.

Sodium amalgam, although it so readily polymerises chinoline,* was found to be almost without action on β-lutidine.

The action of sodium was then tried upon β-lutidine dissolved in toluene; two products were obtained, one solid, the other liquid. The solid substance on being dissolved in hydrochloric acid, and fractionally precipitated as before, gave two precipitates.

Number of precipitate.	Percentage of platinum.
I	25·30
II	33·33

The fluid portion treated as before gave—

Number of precipitate.	Percentage of platinum.
I	26·14
II	30·69

The results, while proving that β-lutidine is polymerised by the action of sodium, show also that at least two substances are formed, and that separation is not easily effected by fractional precipitation with platinic chloride. It will be seen that the second precipitate from the hydrochlorate of the solid base gave for the platinum a number almost exactly agreeing with that required for the platinum salt of dibetalutidine $C^{14}H^{18}N^{2}.HClPtCl^{4}$, which requires 33·53 per cent. of platinum.

Compound of β-Lutidine with Nitrate of Silver.

I have shown in my paper "Researches on Isomeric Alkaloids,"† that β-lutidine combines *directly* with platinic chloride; it does the same with nitrate of silver.

When β-lutidine is added to an aqueous solution of nitrate of silver, a white curdy precipitate is thrown down, it dissolves in alcohol, and is reprecipitated by water as a glittering mass of snow-white crystals. These latter crystallise readily from alcohol in beautiful stellar groups. On analysis the following numbers were obtained:—

* "Proc. Roy. Soc.," vol. 31, p. 536.

† "Proc. Roy. Soc.," vol. 13, p. 308. There is a misprint in this paper, the formula for the direct compound of β-lutidine with platinic chloride is given as $C^7H^9N.PtCl$, it should have been $C^7H^9N.PtCl^2$; or, in modern notation, (Pt = 198) $2(C^7H^9N)PtCl^4$.

	Experiment.	Calculation.		
Carbon	50·97	51·32	C^{21}	252
Hydrogen	5·98	5·50	H^{27}	27
Nitrogen	....	11·41	N^4	56
Oxygen	....	9·78	O^3	48
Silver	21·03	21·99	Ag	108
		100·00		491

agreeing with the formula—

$$3(C^7H^9N).Ag.NO^3.$$

Compound of Hydrochlorate of β-Lutidine with Chloride of Uranyl.

On mixing solutions of hydrochlorate of β-lutidine and chloride of uranyl, a beautiful yellow salt is formed; it gave the following numbers:—

	Experiment.	Calculation.		
Carbon	26·90	26·67	C^{14}	168
Hydrogen	3·39	3·17	H^{20}	20
Nitrogen	....	4·44	N^2	28
Chlorine	....	22·54	Cl^4	142
Uranium	....	38·10	Ur^2	240
Oxygen	....	5·08	O^2	32
		100·00		630

agreeing with the formula—

$$2(C^7H^9N.HCl).Ur^2O^2Cl^2.$$

Compound of Sulphate of β-Lutidine and Sulphate of Uranyl.

On mixing sulphate of uranyl with sulphate of β-lutidine a yellow mass consisting of small crystals is formed on long standing. The substance was dried at 100°, and burnt with the annexed result:—

	Experiment.	Calculation.		
Carbon	19·10	19·27	C^{14}	168
Hydrogen	2·54	2·29	H^{20}	20
Nitrogen	....	3·21	N^2	28
Sulphur	....	14·68	S^4	128
Uranium	....	27·52	Ur^2	240
Oxygen	....	33·03	O^{18}	288
		100·00		872

The above numbers agree with the formula—

$$2(C^7H^9N)H^2SO^4.Ur^2O^2.3(SO^4).$$

Picrate of β-Lutidine.

When β-lutidine is added to a strong boiling solution of picric acid, most of the salt formed settles out as an oil, owing to its insolubility and fusibility, but it becomes a solid crystalline mass on cooling. On redissolving the solid in boiling water, and allowing the solution to cool, the vessel becomes filled with brilliant yellow needles. They were burnt with oxide of copper, with the necessary precautions, and gave the following numbers :—

	Experiment.			Mean.	Calculation.		
Carbon........	46·77	46·75	46·80	46·77	46·43	C^{13}	156
Hydrogen.....	4·11	4·16	3·94	4·07	3·57	H^{12}	12
Nitrogen......	....	....	....	....	16·67	N^4	56
Oxygen.......	....	....	....	....	33·33	O^7	112
					100·00		336

The formula is, therefore—

$$C^6H^2(H.C^7H^9N)3(NO^2).O.$$

Action of Chlorine on β-Lutidine in presence of Iodine.

The chlorination of β-lutidine was effected by Hugo Müller's method; for this purpose iodine was added to the alkaloid, the mixture was heated to 100°, and a current of chlorine was passed through until complete saturation. The product was a dark reddish-brown fluid, which was distilled. The portion boiling below 220° was washed with a dilute solution of hydrate of sodium, and then treated with hydrochloric acid, a viscid green substance of peculiar odour remained undissolved. On adding solution of platinic chloride to the filtered liquid, a granular precipitate was obtained; it was washed, dried, and the percentage of platinum determined: it amounted to 23·49 per cent. The formula $2(C^7H^6Cl^3N.HCl)PtCl^4$ requires 23·74. This result shows that the product is a trichlorinated β-lutidine retaining the basic properties of the original alkaloid.

V. "On the Effect of the Spectrum on the Haloid Salts of Silver, and on Mixtures of the same." By Captain Abney, R.E., F.R.S. Communicated to the Royal Society at the request of the Committee on Solar Physics. Received December 6, 1881.

There have been many investigations as to the sensitiveness to the spectrum of the haloid salts of silver, from the very earliest days of photography; and when the results obtained by the different investigators are compared one with another there are often very wide discrepancies apparent. It appeared to me that it was desirable if possible to examine the subject afresh, and to endeavour to reconcile or to explain as far as possible these discrepancies.

The earlier investigators, such as Herschel, Hunt, Draper, and Becquerel, added much to the knowledge of the subject, but their researches were carried on at a time when the modern modifications and more powerful means of development of an image were unknown. Later investigators, including such eminent names as H. W. Vogel and Eder, have availed themselves of the modern appliances, but their results are not always consistent one with another.

In the following researches points are brought out which are, it is believed, new and deserving of attention, not only on account of their applicability to the practical working of photography, but also because they throw a light on molecular physics.

For solar photography it is essential that a knowledge of the relative effect of the various parts of the spectrum should be known, since, if the photo-heliograph be adjusted for one particular part, and the films employed be more sensitive to another part, it is manifest that no great sharpness of image can be obtained. The following researches it is believed show what an enormous effect the mixture of haloid salts has in shifting the position of maximum effect, and it may be possible to either alter the achromatism of the objectives employed, or else solely to use the sensitive compound to which the objective is at present adapted.

Apparatus employed.—The spectroscope employed in these researches was that already described "On the Effect of the Atomic Grouping of Molecules."* Two prisms of medium dense and colourless flint-glass were used to obtain the necessary dispersion. They were set to have the angle of minimum deviation near G. The angle of dispersion between A and H was about $6\frac{1}{2}°$, the length of spectrum between these two lines was about $2\frac{1}{4}$ inches, the spectrum in the ultra-violet extending some $1\frac{1}{4}$ inch beyond H, and the infra-red about $\frac{3}{4}$ of an inch beyond A. The whole spectrum as given by the prisms under consideration thus had a length of $4\frac{1}{4}$ inches, a length in which all phenomena could be fully recognised and measured.

Sources of Light.—The sources of light employed were the sun and the crater of the positive pole of the electric light. Images of these sources were thrown on the slit by means of a condensing lens alone in the second case, and by it and a heliostat in the first case.

Vehicles holding the Sensitive Salts.—The sensitive salts were held *in situ*, in paper, in gelatine, and in collodion, in the last vehicle the salts being prepared either as emulsions in fluid collodion or by the ordinary silver nitrate bath process. In gelatine the salts were all

* "Phil. Trans." for 1881: Part 3.

prepared as emulsions; when in paper they were prepared by soaking it in a soluble haloid salt, and floating on solution of silver nitrate. The question of the production of sensitive silver haloid salts on a metallic silver plate I have left to be considered later, since it has no direct bearing on the points I wish to discuss in this communication.

Exposures.—When it was desired to obtain the expression of the action of the spectrum by its direct effect without the intermediary of a developer, the slit of the spectroscope was opened to a width of $\frac{1}{20}$ of an inch, and the exposure prolonged for five to twenty minutes. When the effects had to be shown by development the slit was closed to $\frac{1}{300}$ of an inch, and exposure given varying between $\frac{1}{4}$ second and one minute or even two minutes. By having a shutter at the slit of the spectroscope it was easy to give two exposures on the same plate or paper, using half the length of the slit for each exposure. This was excessively convenient, since it allowed the different phenomena arising from different methods of exposure to be accurately compared together. The principle on which the exposures were given was as follows:—1st. An exposure was given to the plate, when a pale solution of chromate of potash so dilute as to cut off the spectrum above E, was placed in front of the slit. This exposure was in all cases prolonged in order to see if there was any action produced, however feeble, by the spectrum remaining unabsorbed. The next exposure was always taken with the slit unshaded, and on the same plate (or paper) as the first exposure. After a certain interval of time had elapsed, the yellow chromate was again placed in front of the slit, and the exposure continued. The reason for adopting this plan was that the effect of diffused white light (diffused from the prisms during unshaded exposure) would thus be differentiated. Thus, supposing it was found that the first exposure caused no sign of a change in the sensitive salt by the exposure to the spectrum unabsorbed by the chromate, but that the unshaded spectrum caused an action on these parts, it would be evident that the action of diffused light had played a part in causing such an action.

When such phenomena resulted, plates or papers were first exposed to the unshaded spectrum through the chromate solution, then withdrawn from the camera and exposed to the diffused light of the laboratory for a fraction of a second, or for eight or ten seconds, according as the experiment was to be conducted by development or by direct printing action, and again inserted in the slide and exposed to the action of the partially absorbed spectrum. If the experiments were rightly conducted, the results of the last two should be confirmatory of the first two exposures. Other plates or papers were then exposed, giving, unshaded, one half of the slit of a short period, and the other half for a period ten to twenty times as long. By this system all the phenomena met with could be differentiated and traced.

Localities of Maximum Action.—I have followed the usual custom of writers on this subject, and shown the top of my curves as the place of maximum action. Although this correctly shows what appears on the photographic plate, yet in all cases it is apt to give a false notion regarding the effect of the spectrum. If we look at the energy of the spectrum in its different localities, we find that it rapidly decreases as it approaches the violet and ultra-violet. If this diminution of energy be taken into account, it will be found that usually the point of maximum effect nearest the violet indicates the region where the absorption of the rays becomes total, and that the shading off towards the ultra-violet is really only due to the diminished energy of that part of the spectrum. In other cases, as, for instance, where there are two maxima, this will not apply to the second maximum.

Silver Iodide.

Visible Effect of the Spectrum on Silver Iodide.—If paper be soaked in a 10 per cent. solution of potassium iodide and dried, and then be floated on a 10 per cent. solution of silver nitrate and exposed whilst moist,* the spectrum will be impressed in five minutes, as given in fig. 1, where it will be seen that the whole visible spectrum is impressed. Similar paper if exposed to the spectrum coming through a weak solution of potassium chromate, exhibits after ten minutes a slight action in the least refrangible region (fig. 3). If, however, the paper be exposed for ten seconds to diffused light and then be exposed to the same spectrum as the last the action is more intense than before, though the exposure be for only two minutes (fig. 2). From this we learn that part of the action of the spectrum in fig. 1 is due to the action of diffused light. It next remained to trace the action on the different silver compounds existing in this paper, which was ordinary sized saxe paper. Paper was prepared as before, but washed in common water till nearly all excess of silver nitrate was eliminated, and it was then given a wash of potassium nitrite, an absorbent of iodine. Such paper was exposed to the spectrum, first, coming through chromate, second, unshaded. The print obtained is that shown in fig. 4, by which it will be seen that the same limits were reached as before, but that there is not that abrupt descent of sensitiveness near G; evidently some cause of the extreme sensitiveness near this point had been eliminated, and apparently that could only be the silver nitrate and the presence of the potassium nitrite. To test the matter further, paper was prepared in the same manner, but before applying the potassium nitrite it was soaked in common salt and water and washed. This would effectually remove all traces of silver nitrate

* The same action was observed where the paper was allowed to dry, but the darkening was less.

converting it into silver chloride. Exposure for five minutes to the spectrum gave the result shown in fig. 5, in which it will be seen that whilst the most refrangible portion took a grey colour, the small portion below G became a pink, the line of demarcation between the two being well defined. It now seemed probable that the pink part of the spectrum was due to the chloride and the grey to the iodide.

To further investigate the matter, the same paper without iodide was floated on silver nitrate and exposed to the spectrum, with the result given in fig. 6, a very faint trace of action being visible where the paper was exposed for a quarter of an hour to the spectrum transmitted by the potassium chromate.

Iodised paper prepared as in the first experiment was well washed and simply exposed with the result to be seen in fig. 7. Finally, paper was prepared and washed, then immersed in a weak solution of potassium iodide, washed well and flooded with potassium nitrite, and the result is given in fig. 8. Now, fig. 1 coincides with the observations made by Sir J. Herschel, on paper similarly prepared, in 1842, and described in the "Phil. Trans." for 1843, and he classes this spectrum as due to the silver iodide. It will be seen that the printed spectrum due to silver iodide is that given in fig. 8, and that the tail extending to the least refrangible end is really due to the action of that region on the organic salt (and perhaps chloride) of silver present in the paper. Further, it will be seen that the greater part of the darkening in fig. 1 of that tail is due to the action of the different rays after or whilst diffused light has acted or is acting on that organic compound. Confirmatory experiments were made with pure silver iodide in collodion with excess of silver nitrate, and also without such excess, with the result shown in fig. 8.

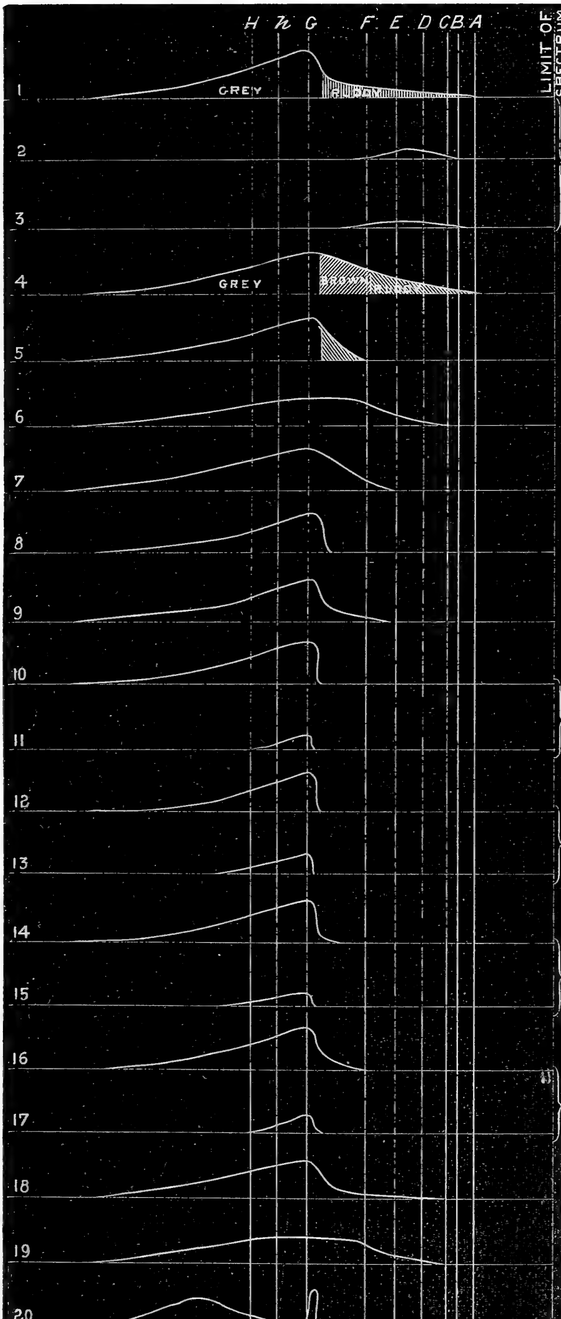
If further confirmation were required, it was only necessary to add to a film of collodion containing the iodide and excess of silver nitrate a small trace of organic matter, such as resin or albumen, and the result given in fig. 9 was obtained.

Thus, then, we may say that the parts of the spectrum capable of direct action on silver iodide are shown in fig. 8.

The next point to which my attention was turned was to ascertain the true region of the spectrum which was active on silver iodide when developed.

There are several developers for silver haloids:—

Acid developers ..	1st.	Ferrous sulphate and silver nitrate.
	2nd.	Pyrogallic acid " "
	3rd.	Gallic acid " "
Neutral organic iron developers	4th.	Ferrous oxalate.
	5th.	Ferrous citro-oxalate.
Alkaline developers	6th.	Pyrogallic acid and ammonia.



$AgI+AgNO_3$ on paper ... *Print.*

" " ... ... *Print.*

" " ... ... *Print.*

AgI on paper washed from excess of $AgNO_3$ and treated with KNO_2. *Print.*

AgI on paper washed from $AgNO_3$ soaked in NaCl, washed from excess and exposed with KNO_2. *Print.*

Paper floated on $AgNO_3$ ... *Print.*

AgI on paper washed from excess of $AgNO_3$, ruddy tint. *Print.*

AgI on paper washed from excess of $AgNO_3$, treated with KI and KNO_2; or AgI in collodion. *Print.*

$AgI+AgNO_3$ in albumen ... *Print.*

AgI prepared in bath treated with KI, washed, redipped in silver bath, developed with pyrogallic acid. *Developed* (long exposure).

Ditto ditto ... ... (short exposure).

AgI purified and exposed in presence of sensitiser, developed by acid or alkaline developer. *Developed* (long exposure).

Ditto ditto ... ... (short exposure).

AgI unpurified, treated and developed as above. *Developed* (long exposure).

Ditto ditto ... ... (short exposure).

AgI with trace of AgCl or AgBr, developed by acid or alkaline method. *Developed* (long exposure).

Ditto ditto ... ... (short exposure).

$AgI + AgNO_3$ in albumenised collodion, or on paper washed, acid development. *Developed.*

$AgI + AgNO_3$ in albumenised collodion, or on paper washed, ferrous citrate developer. *Developed.*

$AgI+AgNO_3$ prolonged exposure. *Developed.*

Now, the first three gave precisely similar results as did the last three. It will, therefore, be unnecessary for me to state for every experiment which developer was used. With collodion or gelatine plates I preferred the 2nd and the 4th developers, and with paper the 3rd and the 5th.

It may be necessary to point to the different materials employed. In the first place very pure potassium iodide was obtained by Stas's method, and as much as would dissolve was put into collodion; by the free use of water with the alcohol as much as 4 grs. was dissolved. This was employed with a silver bath prepared in the usual way, containing 35 grs. of silver nitrate to each ounce of water.

5 grs. of commercial cadmium iodide was dissolved in an ounce of collodion, and this was also used with a silver nitrate sensitising bath. The pyroxylin forming the collodion was carefully selected. Before taking into use it had been precipitated from solution by water, washed in alcohol, again precipitated, and washed and dried, and then redissolved in equal parts of pure ether and alcohol at the rate of 7 grs. to each ounce. Such a solution after prolonged exposure when impregnated with nitrate of silver gave no reduction of the salt.

The emulsions of silver iodide were made by dissolving 6 grs. of silver nitrate in alcohol, adding this to collodion, and gently adding the equivalent to 5 grs. of silver nitrate of the soluble iodide (dissolved in alcohol) to it. This formed a perfect emulsion of silver iodide in the presence of a slight excess of silver nitrate, and also of course of the soluble nitrates formed by the double decomposition of the above. I may at once say that the presence or absence of these soluble nitrates had no effect at all on the results, and may at once be dismissed from further consideration.

Gelatine emulsion was prepared in the same manner, keeping in mind, however, that in this case it was prepared with an excess of soluble iodide instead of silver nitrate. It is well to remark that it is impossible to get a fine emulsion of silver iodide in collodion unless the plan indicated above be followed of first dissolving the silver nitrate in the collodion and then adding the iodide to that, in addition to which it is necessary that the silver nitrate be in excess or the emulsion becomes granular. With gelatine the emulsification is an easier matter, but in order to prevent spontaneous decomposition of the gelatine it is necessary that the soluble iodide be in excess. Emulsions of both kinds were "washed" by the usual methods known to photographers. In the case of the collodio-iodide of silver great care was taken that nothing but pure distilled water was employed.

It will be well to show here how it was we ascertained that nothing but pure iodide of silver exists in a film. The impurities to be met with are oxides, chlorides, and bromides. Now when an oxide of silver, or silver chloride or bromide is placed in a solution of potassium or other soluble iodide, the silver compound is at once decomposed, and silver iodide formed in its place. If, then, a film of iodide of silver in collodion (whether prepared from an emulsion or by the bath process) be washed from silver nitrate, and be then immersed in a weak solution of potassium iodide (it must not be strong or it will dissolve out the silver iodide from the film) or other soluble iodide, it may be seen that there will be nothing but silver iodide in the film, all impurities being decomposed. If the film be washed well with distilled water, and again immersed in the bath, or flowed over with some sensitiser, such as potassium nitrite, sodium sulphite, beer, pyrogallic acid, &c., it may be exposed with the certainty that only pure silver iodide is under examination. It was necessary to make these remarks, since the whole of the utility of the research depends on the use of the pure substance, the collodion being absolutely inert as regards the silver salt. The silver iodide emulsion made from the purified potassium iodide proved to contain nothing but the pure iodide, but that prepared with the cadmium and other iodides, as will be seen, proved untrustworthy as to purity. It was owing to this that I was led into a mistake in a paper which appeared in the "Proceedings of the Royal Society," wherein I stated that owing to the oxygen-absorbing properties of potassium nitrite, I was able to obtain an image lower than ordinary. It seems now that this may have been due to a contamination of bromide or chloride, or to the formation of silver nitrate, any of which would have given me the same results.

One word also as to the neutral or alkaline developer employed. It has been customary to state that silver iodide is unamenable to alkaline development. This is, however, not the case. The ferrous oxalate and the ferrous citro-oxalate bring out a distinct image, as does pyrogallic acid and ammonia, when no restraining iodide is employed. In all dry plates prepared with the iodide and other silver haloids, the iodide is developable (though it gives a weakly image compared with that due to other salts) by the alkaline or organic iron developer.

A plate was coated with cadmium iodised collodion, and placed in the bath for a couple of minutes, and exposed to the spectrum. The top half of the slit was uncovered for one second, the bottom half for ten seconds; the results are seen in figs. 14 and 15. The development took place by the acid developer. Plates similarly prepared and washed, and then, similarly exposed, also gave as results figs. 14 and 15. When using ferrous oxalate, the cadmium emulsion also gave the same result. Plates coated with a film of the same collodion, washed, and then immersed in a weak solution of potassium iodide or cadmium iodide, again washed clean with distilled water, and finally treated with silver nitrate, beer, pyrogallic acid, potassium nitrite, when developed by the acid or other methods, gave the results in figs. 10 and 11. The purification of silver iodide by this treatment cut off the small tail on the least refrangible side of G seen in fig. 14. When the pure silver iodide prepared by the aid of the pure potassium iodide was used, figs. 13 and 12 resulted. A plate was next coated with collodion iodised with the pure potassium iodide, immersed in the bath, washed, and then placed in a solution of common salt (1 gr. to 5 oz.), with the result that figures similar to figs. 16 and 17 were obtained.

A plate similarly treated, except that potassium bromide was substituted for the common salt, gave as a result figs. 16 and 17. There was no marked difference whether the plate was developed by the acid developer or by the ferrous oxalate. It would be useless to describe the many other experiments which were made, all tending to prove that the true action of the spectrum on silver iodide in collodion is that given in figs. 10 and 11. No deviation from it has been obtained, unless impurity in the pyroxyline or in the soluble iodide was proved to exist.

With gelatine emulsions of yellow silver iodide, when rendered sensitive by the use of potassium nitrite or silver nitrate, the same action was found to hold good, and the same may be said for plates prepared with albumen as a vehicle, when all the silver was converted into iodide, and the sensitising was effected by potassium nitrite or some other similar sensitiser.

We next come to the iodide of silver when held *in situ* by paper. The same method of preparation was adopted as that given above for the printing experiments. When paper was exposed with the excess of silver nitrate, on acid development fig. 18 was obtained. When developed by an organic ferrous developer, fig. 19 was obtained; figs. 14 and 15 were obtained when similar paper was washed and salted with common salt, and washed again, and then sensitised with potassium nitrite.

Figs. 18 and 19 are worthy of attention. It is seen in fig. 18 that the iodide has much greater power of attracting freshly deposited silver than have the impurities present with it in the paper. On the other hand, fig. 19 shows that the ferrous oxalate developer has more power of reducing the impurity (or rather the reduction is better seen) than it has the iodide.

When silver iodide paper is prepared and washed, and treated with a weak solution of potassium iodide and resensitised by potassium nitrite, figs. 10 and 11 are obtained.

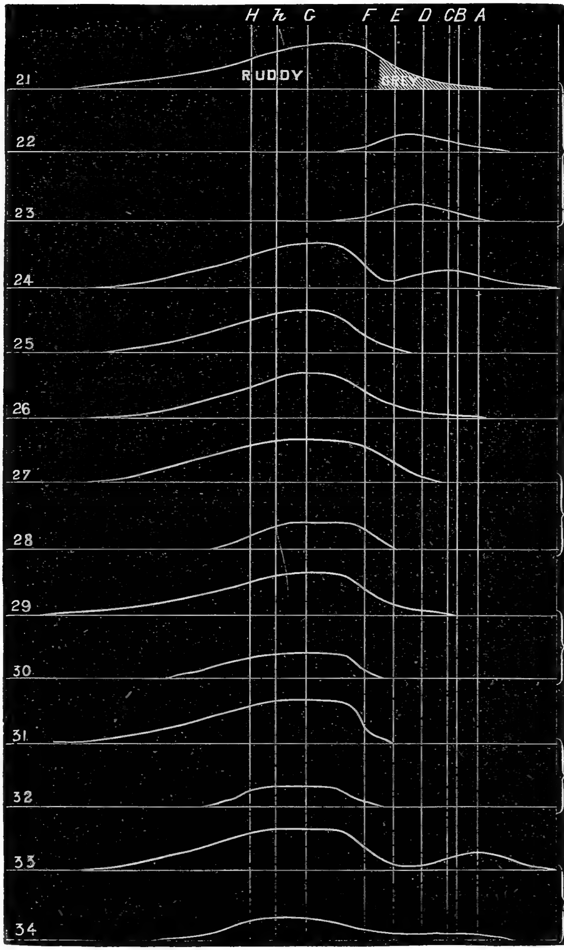
Fig. 20 shows the action of the spectrum on pure iodide when the exposure is very prolonged. It appears as if the sensitiveness on the more refrangible side of G had diminished. This is not the case, however. The prolonged exposure causes a commencement of what is called a reversal of the image due to oxidation, which I have already investigated in the "Philosophical Magazine," 1880, and the maximum effect has, therefore, apparently shifted to the least refrangible side of G, as shown. This is important, since phenomena which have been described and figured by other investigators can be shown to be caused by this reversing action. I shall have to allude to it myself again further on.

What has been noted regarding the action of impurities in the silver iodide points to a method of ascertaining if an iodide or iodine itself is pure. It is believed that the merest trace of impurity may be recognised by this method of spectrum analysis.

Silver Bromide.

When paper is immersed in a 10 per cent. solution of potassium bromide, then dried and floated on a 10 per cent. solution of silver nitrate, and exposed to the action of the spectrum, the visible effect will be observed as shown in fig. 21. Figs. 22 and 23 show the action of the spectrum after filtration through potassium chromate, the former being what is observed after a preliminary exposure to diffused white light, and the latter when the paper has only seen the yellow light. It is needless to go into all the details which were described when silver iodide paper was under examination. The same causes exist for the shape of the curve as they do with the latter paper. It may be interesting to remark that the spectrum observed on paper which has been washed and treated with potassium bromide after sensitising is the same as that shown in fig. 25, whilst when only washed and not treated with the soluble bromide it takes the form of fig. 29. The reason of these differences in shape of curve is apparent when it is remembered how the effects on silver iodide paper were traced to their source.

It must be noted that there are several molecular modifications of silver bromide. The first is that form in which it exists in the paper and also in collodio-bromide emulsions when prepared in the ordinary way; also when prepared in collodion by the bath. This form transmits a yellow-orange tint when white light traverses it. Another form is one which I described in the Bakerian Lecture for 1880, viz. a form which transmits a blue-green tint; and a last form which transmits a grey tint, which is found in gelatine emulsions which have been boiled, or treated with ammonia in the manner which is common at the present day. These three varieties were examined both for the visible action of light and also for development. A plate was coated with the first emulsion named, with the result that the direct action of light gave fig. 25. The blue-green transmitting form gave fig. 24. This form is one which is sensitive to the infra-red rays of the spectrum on development, and it will be seen that the printing action also extended to that region. The printing action on the grey form (which was submitted to the spectrum in a film of gelatine) is shown in fig. 26. On comparing these together, it will be seen that the maximum action commences between G and F (nearer F than G), and that the main difference in their impressed spectra lies in the tails



21	AgBr + $AgNO_3$, on paper ...	*Print.*
22	" " ...	*Print.*
23	" " ...	*Print.*
24	Green AgBr in collodion with or without $AgNO_3$.	*Print.*
25	Orange AgBr in collodion gelatine with or without $AgNO_3$.	*Print.*
26	Grey AgBr in gelatine ...	*Print.*
27	AgBr on paper washed from $AgNO_3$, developed with acid or ferrous citro-oxalate developer.	*Developed* (long exposure).
28	Ditto ditto	(short exposure).
29	Grey AgBr in gelatine, developed alkaline or ferrous oxalate.	*Developed* (long exposure).
30	Ditto ditto	(short exposure).
31	Orange AgBr in collodion or gelatine, developed alkaline ferrous oxalate or acid developer.	*Developed* (long exposure).
32	Ditto ditto	(short exposure).
33	Green AgBr in collodion, developed ferrous oxalate.	*Developed* (long exposure).
34	Ditto ditto	(short exposure).

on the least refrangible side. When the colour transmitted by these three forms is taken into account, these differences are to be expected. Whether the silver bromides were exposed with a slight excess of silver nitrate, or with a slight excess of soluble bromide, no difference in the spectra resulted.

We next come to spectra developed on the different preparations of silver bromide. Fig. 27 represents the action of the spectrum on silver bromide paper, prepared as above, which has been washed. Whether development took place by acid developer or by ferrous citro-oxalate, no difference was observable. Fig. 28 shows the same with a short exposure. When the paper was washed and treated with potassium bromide and then exposed, we have as a result figs. 31 and 32. The slight difference in the pairs of figures results from the presence in one case of inorganic matter combined with silver, and in the other case its absence.

When a plate is coated with collodion containing cadmium bromide, zinc bromide, or potassium bromide, and placed in a strong silver nitrate bath, and developed with either acid developer or with ferrous citro-oxalate, we get curves similar to figs. 31 and 32. The same figures also represent the action of the spectrum on collodio-bromide emulsions transmitting orange light by any kind of development. This applies equally whether the plate be exposed wet or dry, or whether exposed in the presence of silver nitrate or other inorganic sensitisers.

Figs. 29 and 30 show the results obtained when using gelatine bromide plates with the silver bromide in the grey molecular state, whether exposed with an inorganic sensitiser, or without, and whether developed with an acid, alkaline, or organic iron developer.

Figs. 33 and 34 represent the action on the blue-green molecular form of silver bromide in collodion, when developed and exposed under similar circumstances to the preceding case.

It will be remarked that the direct visible action of the spectrum and the developed image coincide.

The effect of impurity in the bromide is not so marked as it is in the iodide. The presence of iodide except in minute quantities is rare; the haloid most frequently present as an impurity being the chloride. When the spectrum on the chloride is considered, it will be seen that such an impurity is hardly possible to be detected, as the spectra impressed on it are somewhat similar in general character to those on the bromide.

Silver Chloride.

Paper was impregnated with a 10 per cent. solution of sodium chloride and sensitised on a 10 per cent. solution of silver nitrate. Paper thus prepared was exposed to the spectrum in a damp state, and also in a dry state, and the visible impression recorded. Fig. 35 shows the action. When the paper was exposed for twenty seconds to diffused light a different curve as shown in fig. 36 was found; an approach to the same curve being also shown with very prolonged exposure without the preliminary action of light. This is probably due to the action of the diffused light in the prism.*

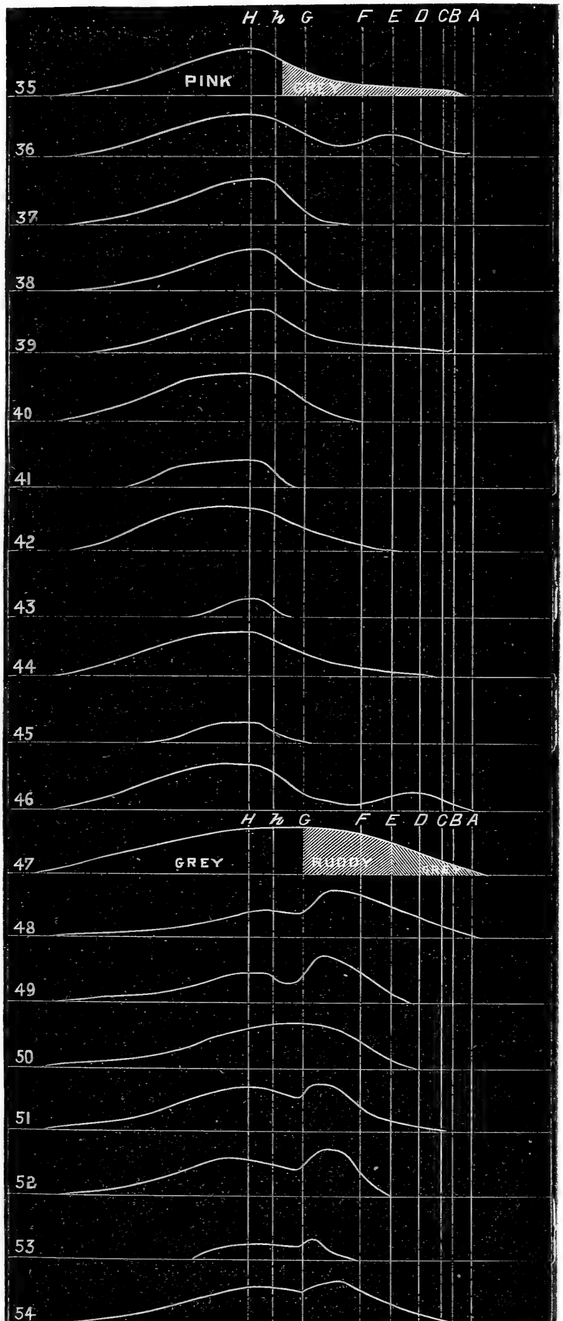
* I have not taken into consideration the spectrum impressed on silver chloride

Similar paper was washed, some was used in this state and other was afterwards treated with a solution of sodium chloride and again washed, leaving thus only a trace of an organic salt of silver in the fibre. The action of the spectrum on the simply washed paper is shown in fig. 37. With a short preliminary exposure, traces of an impression between F and C were obtained, tending to show that the preliminary action in fig. 36 was effective on the chloride besides on the organic compound of silver. Fig. 38 gives the action of the spectrum in the chloride which had all traces of silver nitrate removed by the wash of sodium chloride.

To obtain an emulsion of silver chloride in collodion, 20 grains of calcium chloride were dissolved in 1 oz. of collodion, and 1 gr. more, or 1 gr. less, according as excess or defect of silver nitrate was required, than the equivalent of silver nitrate dissolved in another ounce of collodion; the former solution was poured in the later, shaking at intervals, till a perfect emulsion was obtained. In some cases the emulsion was washed in the ordinary way known to photographers, and in others used when made as above, and the films washed or exposed in their natural state. In no case did any difference in the resulting impression of the spectrum appear. I may also state that other chlorides were tried, and there is no apparent difference from those obtained where sodium chloride was employed. Fig. 38 also gives the action of the spectrum on such emulsion, there being no apparent difference between the washed emulsion or the emulsion exposed with an excess of silver nitrate, or with an excess of the soluble chloride, unless it be one of general sensitiveness. In other words, the spectrum seemed to act on the silver chloride in one and the same manner. Fig. 39 shows the printing action on the chloride when enveloped in gelatine. The emulsion was formed in the usual manner habitual amongst photographers, each ounce of emulsion containing about 25 grs. of converted silver nitrate. Fig. 39 has reference to this emulsion after it was heated to its boiling point for half an hour, and when treated with ammonia; when used unboiled it took an impression similar to fig. 38.

When these same preparations of the chloride in gelatine are exposed for a short time to the spectrum and developed with ferrous citro-oxalate developer, or with gallic acid and silver, we get figs. 42, 43, 44 and 45, the first two expressing the result of the unboiled emulsion which transmits yellow-orange light, and the two latter numbers that on the boiled emulsion which transmits a blue-grey light.

visibly darkened by the light. This, as is well known, is impressed throughout the spectrum, and takes the approximate colour of the spectrum. This is true whatever vehicle is used to hold the silver chloride, and also whether exposed in the presence of an excess of silver nitrate or other sensitiser, and also when organic compounds of silver are mixed with it.



$AgCl+AgNO_3$ on paper ...	*Print.*
$AgCl+AgNO_3$ on paper, slight preliminary exposure.	*Print.*
AgCl on paper washed from excess of $AgNO_3$.	*Print.*
AgCl on paper washed and treated with NaCl and washed again, also collodio chloride of silver, also yellow form of AgCl in gelatine.	*Print.*
Grey form of AgCl in gelatine.	*Print.*
AgCl in collodion in presence of excess of $AgNO_3$ or NaCl developed; ferrous citrate, or acid development.	*Developed* (long exposure).
Ditto ditto	(short exposure).
Yellow form of AgCl in gelatine acid or ferrous citro-oxalate development.	*Developed* (long exposure).
Ditto ditto	(short exposure).
Grey form of AgCl in gelatine, acid, or ferrous citro-oxalate development.	*Developed* (long exposure).
Ditto ditto	(short exposure).
AgCl in collodion given a short preliminary exposure, acid, or ferrous citro-oxalate development.	*Developed.*
$AgI+AgBr+AgNO_3$ on paper, moist.	*Print.*
AgI+AgBr, washed from $AgNO_3$.	*Print.*
Ditto, ditto, developed ferrous citro-oxalate.	*Developed.*
$AgI + AgBr + AgNO_3$, wet plate, developed acid, or alkaline developer.	*Developed.*
AgI+AgBr in gelatine, developed ferrous oxalate.	*Developed.*
AgBr+AgI in collodion, acid or alkaline developer.	*Developed* (long exposure).
Ditto ditto	*Developed* (short exposure).
3AgI+AgBr, on paper ...	*Print.*

The first numbers of these pairs of figures show the result of exposures ten times longer than the exposures shown by the second numbers of the pairs.

Silver chloride in collodion by whatever means prepared, and whether exposed with an excess of silver nitrate, or an excess of soluble chloride, gave figs. 40 and 41, the former being the result of exposure ten times longer than that shown by the latter. The mode of development had no effect on the spectrum developed.

The washed paper gave on development the same result as that shown for the direct action of light, viz., fig. 37. The mode of development had no effect on the result.

The washed paper subsequently treated with a solution of sodium chloride and again washed, when exposed to the spectrum gave on development with either gallic acid, and silver nitrate, or with ferrous citro-oxalate, the same figure as that obtained by the direct action of light, viz., fig. 38.

When a brief preliminary exposure to white light was given to either the paper or the different emulsions, fig. 46 was obtained on development. On looking at figs. 35 to 46 it will be seen that invariably the maximum intensity is reached between H and *h*. According to many authors the maximum is near G, whilst, according to others, it is in the ultra-violet. I have carried out about 200 experiments on the chloride with sunlight and with the electric light, and in no case have I found it possible to alter the maximum. Of course if candle or gas light be used as a source the maximum will be about G, since the ultra-violet rays are almost absent with these. The idea suggests itself that the prismatic arrangements employed may be at fault; in some cases where the most definite results have been registered, a direct vision spectroscope has been utilised. I need hardly say that such an arrangement, from the very nature of the apparatus, is unsuited for photo-spectroscopy. Such a spectroscope transmits very few rays beyond H, and at H their intensity is much diminished. In order to settle the matter to my own satisfaction, I used a diffraction grating with the same results as those shown in the figures under consideration. In a paper read before the British Association in August last, I pointed out the great need of caution in measuring daylight intensity by the chloride, and my subsequent examination of the subject has more than ever confirmed me in my opinion therein given.

Methods of obtaining Mixtures of Silver Iodide and Bromide, Silver Iodide and Chloride, &c.

To test mixtures of the iodide and bromide, paper was prepared by immersing it in a solution of potassium iodide and potassium bromide, the proportion of each being so arranged that there should be definite proportions between each, supposing that each salt was entirely decomposed by the silver nitrate. Unfortunately this is never absolutely the case, and hence the results obtained with the paper must be received with some caution. Chemists know that silver bromide or silver chloride cannot exist in the presence of a soluble iodide, nor can silver chloride in presence of a soluble bromide. Hence when we have an iodide and bromide impregnating paper, the silver iodide will first be formed, and then the bromide; or, again, with iodide and chloride, the silver iodide will first be formed and then the chloride; and, finally, with bromide and chloride, the bromide will first be formed and then the chloride.

It was necessary to make these remarks, as a right conception of the results might not be taken on casually looking at them.

The same remarks apply with equal force when a sensitive film of the double salts is prepared by the ordinary silver bath when very short immersion is given to the plate. The only true way of obtaining definite results seems to be by means of separate emulsions, in which a definite amount of soluble chloride, bromide, or iodide is fully converted into silver chloride, bromide, or iodide, and then to mix these emulsions, after proper washing, in the required proportions. It was in this manner that the emulsions which will be discussed presently were prepared.

I would here call attention to a somewhat remarkable behaviour of silver iodide. It is well known that if silver iodide be prepared with an excess of soluble iodide, it is totally insensitive to light. Thus if we prepare (say) an emulsion in collodion with an excess of iodide, and wash it thoroughly in the usual manner, and after redissolving the pellicle resulting from the washing operations, expose it in the camera, no amount of development will bring out an image. If, however, to such an emulsion but a drop of a bromide or chloride emulsion be added sensitiveness will appear. This seems to be due to the last trace of soluble iodide being converted into silver iodide.

Mixtures of Silver Iodide and Bromide.

Equal Equivalent Proportions of Iodide and Bromide.—Paper was soaked in a solution of equivalent proportions of soluble iodides and bromides, and, after drying, was sensitised on a 10 per cent. solution of silver nitrate for such a time that the back of the paper became thoroughly damp. The silver nitrate solution was acidified in order to prevent the formation of any sub-salts.

A strip of such paper was exposed to the spectrum whilst moist, and the printing action noted. The result is given in fig. 47. Similar paper was washed and treated with potassium nitrite, and exposed whilst moist; the effect of the action of the spectrum is seen in the same figure.

Paper was next washed, and portions were treated with a solution of potassium bromide, and again washed. Strips of these two specimens were dried and exposed to the spectrum, and in both cases the printing action is seen in fig. 48. Similar papers, in a moist state, were also exposed without any deviation of the result. Again, paper which had been prepared as above was allowed to dry with the excess of silver nitrate on it, and exposed, and fig. 48 again approximately resulted; as also it did when the washed paper treated with potassium nitrite was dried.

The difference between curves 47 and 48 is very remarkable, and at first sight might not seem to admit of explanation. A study of the experiments described, however, affords a clue to the apparent incongruity of the results. According to text-books on chemistry, bromine will displace iodine in combination, whilst iodide displaces bromide. Later researches seem to modify the first statement to a certain extent. Bromine will only displace a definite proportion of iodine when it is in excess; but for our purpose we may take the text-book statement as practically correct. When the paper was exposed wet with either silver nitrate or potassium nitrite (I may remark that other halogen absorbents gave the same result) the iodine and bromine liberated by the action of light would be at once absorbed by them; in the one case silver iodide (or bromide) and silver iodate (or bromate) being formed, and in the other potassium iodide (or bromide); so that each of the two kinds of sensitive salt would have its full action. When the paper was washed and exposed in a dry state the result would be different, and the question would arise, what would become of the iodine and bromine liberated by light?

If silver iodide be exposed to light and treated with a trace of bromine, the sub-iodide combines with the bromine, and all trace of the action of light is destroyed. Thus when the mixture of iodide and bromide is exposed to light, both iodine and bromine being liberated, the bromine will at once combine with the sub-iodide and destroy it. Thus,

$$Ag_2I+Br=Ag_2IBr,$$

the only factor remaining being the sub-bromide, which is developable. Now it may be said that the iodine liberated should also destroy the sub-salts; but it is a matter of fact that, in the presence of light, it has no power of destroying the sub-iodide, since it is immediately again shaken off from the molecule.* Iodine can destroy the sub-bromide molecule, and form a new saturated molecule; thus,

$$Ag_2Br+I=Ag_2BrI.$$

* [At the same time it must be noted that the iodide is much less sensitive of light when no absorbent of iodine is present. This is fully accounted for by the immediate recombination of, at all events, a portion of the iodine liberated with the sub-iodide molecule.—Dec. 19.]

Whether the two molecules Ag_2BrI and Ag_2IBr have the same value is a moot point, but the evidence tends to show that such is the case. If the equivalents of bromide and iodide were equal, that is, if the bromide and iodide of silver were equally distributed, supposing both the above actions took place, the locality of the spectrum in which the iodide and bromide are equally sensitive should show an almost entire destruction of a developable image, and also of a printed image.

This locality is doubtless about G, and when we come to analyse the curve in fig. 48 we see that there is very small effect about G, whilst there is an increased effect between G and F. Now, to test the matter further, paper prepared with washed silver bromide was exposed to light till it darkened thoroughly, and such paper was treated with a very dilute solution of iodine, and then exposed in the spectrum, with the result given in fig. 74, in which it will be seen that the new molecule is more sensitive to the green between G and F than above G; in fact, we have very little action comparatively at G and above it. In this case we have then a paper prepared in which there is an absolute imitation of the action that takes place in the mixed iodide and bromide. It cannot be said that by this treatment we have $Ag_2I_2+Ag_2Br_2$, since the molecule formed by light is Ag_2Br, and the addition of the iodine is simply to form Ag_2BrI, which is very different from a simple mixture. This experiment then seems to show that this new molecule is more sensitive to the blue-green than it is to the violet. The point then comes as to how, when the original paper is exposed to the spectrum, we have not only a fall of sensitiveness at G and beyond it, but also a greater sensitiveness in the green. Now, silver iodide, as has already been shown, is not in the least sensitive to beyond a very small region below G; therefore, in the green the only component of the mixture of bromide and iodide that can be acted upon is the bromide. As we see when bromide is acted upon one atom of bromine is liberated from the molecule; thus,

$$Ag_2Br_2=Ag_2Br+Br.$$

The liberated atom of bromine immediately attacks the molecule of iodide in its immediate neighbourhood and forms a new bromo-iodide molecule liberating iodine. Thus

$$Br+Ag_2I_2=Ag_2IBr+I,$$

and the iodine either escapes or else forms the molecule Ag_2BrI; thus

$$Ag_2Br+I=Ag_2BrI.$$

Here then it is probable that we have a new saturated molecule formed by the action of light, which on formation is susceptible of being acted on by light in its turn. Whether iodine or bromine is liberated from this new molecule I am not at present prepared to state, but it is my belief that it is the iodine, since density in development by the alkaline method is readily obtained when experimenting with it.

To sum up, the difference in shape between curves 47 and 48 seems to depend on the destruction of the sub-iodide when formed, and its conversion into a new molecule, which is sensitive to the blue-green, the same new molecule being formed by the liberation of the bromine from the molecule of silver bromide when the sub-bromide is formed. In the case of the paper which is dried in the presence of silver nitrate and potassium nitrite the same result occurs. Bromine and iodine attack these salts when in a crystalline state with difficulty, and hence will in preference form the new molecules as before.

Fig. 49 shows the curve of washed paper when developed with ferrous citro-oxalate, and nearly the same result is seen when the development proceeds by acid development, the difference being that the dip in the curve between *h* and G is less pronounced. To illustrate this further, in Fig. 50 we have the case of a collodion film containing equal parts of silver iodide and silver bromide and an excess of silver nitrate, the latter salt absorbing both the iodine and bromine liberated. In fig. 52 we have the results obtained from the same film, but thoroughly washed from all excess of silver nitrate. Whether the plates be developed by acid, alkaline, or an organic ferrous salt, the curves remain in all essential particulars the same. In fig. 51 we have the curve resulting from the same mixture (equal equivalent proportions) held in gelatine when developed by ferrous oxalate or alkaline developer. At first sight it might be said that this action is really due to the "reversing action" of light, of which I have treated in the "Proceedings of the Royal Society," in 1878, and in the "Philosophical Magazine" for 1880. That this is not the case is shown by fig. 53, in which the exposure was exceedingly short; in fact, when very quick exposure was given the curve started at *h* and reached a maximum as shown in fig. 53. These results are exceedingly interesting and important. There is a figure showing something somewhat similar in Vogel's "Lehrbuch der Photographie," Berlin, 1878, but there is no explanation of the cause, nor has it been noticed by any other observer, as far as I am aware.

Three Parts of Iodide to One of Bromide.—When we take three equivalents of silver iodide to one of bromide the curves are somewhat modified. When washed paper prepared with the above proportions is allowed to print in the spectrum, we have the curve shown in fig. 54. When exposed damp in the presence of silver nitrate or other inorganic sensitiser, we have almost a facsimile of the curve in fig. 47.

Washed paper developed with acid developer shows that the proportion of iodide is so large in comparison to the bromide that the sub-iodide is not all destroyed, and we get the maximum corresponding with the maximum of pure silver iodide, fig. 55. The same paper developed with ferrous citrate shows a slight dip near G, fig. 56. The difference in 55 and 56 is seemingly due to the fact that silver iodide has more attractive power for precipitating metallic silver than has the bromide (a fact which is well known) and that the bromide is more amenable to reduction than is the iodide.

Figs. 57 and 58 are well worthy of attention. They are the results of the exposure of the same plate for different lengths of time to the spectrum. It was prepared in the silver nitrate bath and exposed in the presence of free silver nitrate. Taking fig. 57 alone, it might be supposed that we had a similar case to that which we have recently considered, since we find an extraordinarily (apparent) greater sensitiveness in the green than in the violet, and yet we have the image formed in the presence of an excess of silver nitrate, which would be against the theory I have promulgated. Fig. 58, however, clears up the discrepancy: the maximum is found to be at G, and in this case the dip in the curve of fig. 57 is caused by the reversing action alluded to.

Fig. 59 gives the curve obtained by the above mixture of three parts of iodide to one of bromide; when emulsified in gelatine the bottom curve shows a short exposure.

One Part of Iodide and Three of Bromide.—We now come to a mixture of one part of silver iodide to three of bromide. I have not described the printed spectra since they correspond nearly with figs. 47 and 48.

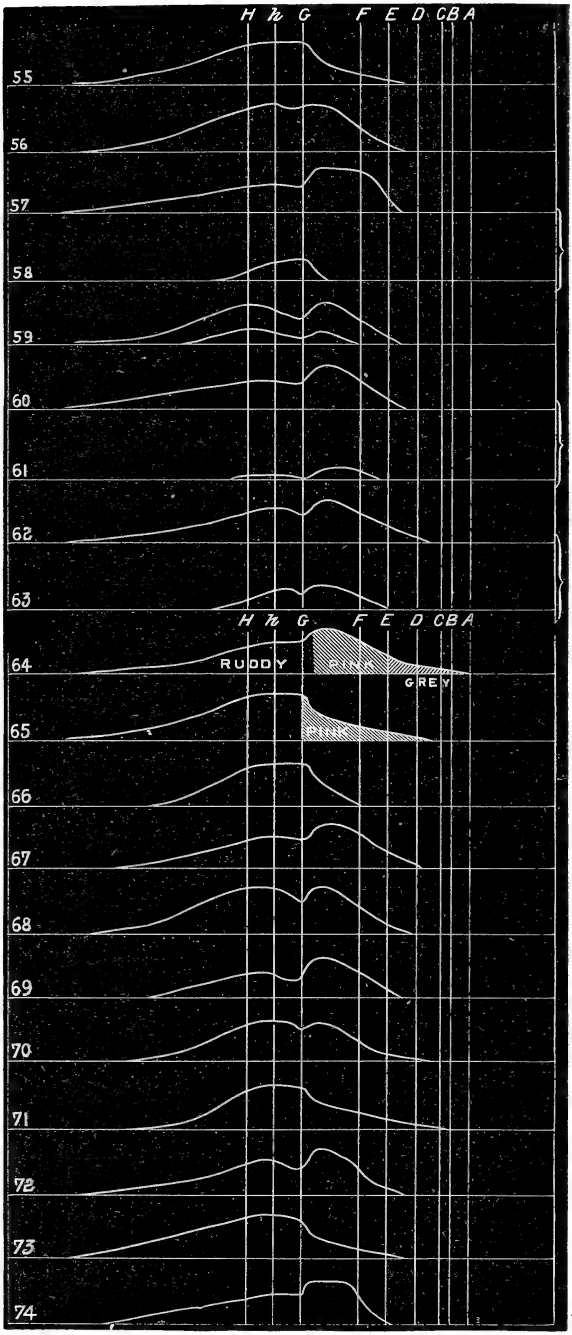
If we compare the curves in figs. 60 and 57 we see a strange similarity between them, but if we take into consideration fig. 61, which is that due to a short exposure on the same plate, we shall at once see that the dips about G are due to two different causes; the dip in fig. 61 is caused by the formation of the new molecule. Figs. 60 and 61 are also the curves shown by paper prepared with the above equivalents of iodide and bromide, and also of the same in collodion when developed by an organic ferrous salt. When developed by acid development, the curve in the more refrangible region is a little more pronounced in character.

Figs. 62 and 63 show the same equivalents emulsified in gelatine and developed by ferrous oxalate.

The different equivalent proportions of bromide to iodide, it will be noticed, show themselves in the curves more particularly when a comparison is made between figs. 51, 59, and 62.

Mixture of Iodide and Chloride.

Three Equivalents of Iodide to One of Chloride.—When paper is prepared with three equivalents of silver iodide to one of



$3AgI+AgBr$ on paper developed gallic acid.	*Developed.*
Ditto, developed ferrous citrate.	*Developed.*
$3AgI+AgBr+AgNO_3$ collodion, wet plate, acid or alkaline developer.	*Developed* (long exposure).
Ditto ditto	(short exposure).
$3AgI+AgBr$ in gelatine, alkaline, or ferrous oxalate developer.	*Developed* (long and short exposure shown).
$AgI+3AgBr$ on paper or in collodion, ferrous citro-oxalate developer.	*Developed* (long exposure).
Ditto ditto	(short exposure).
$AgI+3AgRr$ in gelatine, ferrous oxalate developer.	*Developed* (long exposure).
Ditto ditto	(short exposure).
$3AgI + AgCl + AgNO_3$ on paper, or ditto washed, both dry.	*Print.*
$3AgI+AgCl+AgNO_3$ wet, or $3AgI+AgCl+KNO_2$ wet.	*Print.*
$3AgI + AgCl + AgNO_3$, or $3AgI + AgCl + KNO_2$ on paper, developed with gallic acid or ferrous citro-oxalate.	*Developed.*
Washed $3AgI+AgCl$ on paper, ferrous citro-oxalate developer.	*Developed.*
$3AgI+AgCl$ in gelatine, developed ferrous oxalate.	*Developed.*
$AgI+AgCl$ in gelatine, developed ferrous oxalate.	*Developed.*
$AgI+3AgCl$ paper, washed.	*Print.*
$AgI+3AgCl+AgNO_3$ wet.	*Print.*
$AgI+3AgCl$ in gelatine, or on paper, developed with ferrous citro-oxalate or acid developer.	*Developed.*
$AgI + 3AgCl + AgNO_3$, acid developer.	*Developed.*
AgBr exposed to light treated with I, exposed to spectrum.	*Print and also developed.*

chloride and washed and dried, or if exposed in the presence of dried silver nitrate or dried potassium nitrite, we have the curve shown in fig. 64. If, on the other hand, we have the same paper exposed moist, with silver nitrate or potassium nitrite we have the curve shown in fig. 65. The reasoning applied to the mixture of iodide and bromide applies with equal force here, the results being modified for the shift of maximum of the chloride which lies about $\frac{1}{2}$ H*h*. In fig. 64 the most refrangible part of the spectrum as far as G is ruddy, between G and F a pink colour, and beyond that grey. This difference in colour indicates (as it does in all other photographed spectra where different colours are impressed or developed) a difference of compound acted upon. According to our theory the molecule acted on beyond G in the violet and ultra-violet would be $Ag_2I_2+AgICl$, and between G and E $Ag_2ICl+Ag_2Cl_2$ alone. The grey here is probably due to the organic silver compound formed in the paper.

Fig. 66 shows the same equivalents if contained in paper or collodion, and when exposed to light in the presence of moist silver nitrate or other inorganic sensitiser and developed by acid or ferrous citro-oxalate developer, the slight modification due to the former developer noted above still holding good. Fig. 67 shows the same paper or collodion emulsion washed and developed with ferrous citro-oxalate. Fig. 68 shows the same when emulsified in gelatine and developed with the same ferrous developer. There is a difference in the curves obtained with collodion and gelatine, but not more than is explainable by the fact that the former is essentially porous and the latter almost continuous.

One Equivalent of Iodide to Three of Chloride.—When three equivalents of silver chloride are taken with one of iodide, we have, on printing a washed paper, the curve shown in fig. 70; exposing the same paper moist in the presence of silver nitrate we have fig. 71; the reasoning given when the mixture of bromide and iodide was under consideration holds good. Figs. 72 and 73 show the same equivalents of sensitive salts held in paper, the former showing the action of development on washed salts and the latter on the same exposed in the presence of moist silver nitrate.

Fig. 69 shows the effect of the spectrum on *equal* proportions of the iodide and chloride when emulsified in gelatine.

Paper and also collodion films containing silver chloride were blackened in the light and treated with a solution of iodine till the darkening was obliterated, washed, and then exposed, with or without sensitisers; we had nearly the same results on printing and on development as shown in fig. 74, hence, it was thought useless to repeat the curve there shown. (The same applies to darkened bromide treated with iodine, exposed to the spectrum and developed.)

This appears to be a confirmation of the view already propounded regarding the formation of a new molecule, in the case of the chloride and iodide the new molecule taking the form of Ag_2ClI, as already indicated.

From these results we may observe that to obtain a compound sensitive to the green a mixture of iodide and bromide, or iodide and chloride, should be employed, the former in preference to the latter, since it is more sensitive. The same sensitiveness to daylight with the former in gelatine plates can be obtained as when using pure bromide alone, the sensitiveness being preserved by a shift of the maximum to the green.

Mixtures of Silver Chloride and Bromide.

There is nothing special calling for remark in a mixture of these two sensitive salts. The printed spectrum and the developed spectrum seem to be a combination of the spectra impressed on each individually, a slight prolongation towards the least refrangible end taking place.

Mixture of Silver Iodide, Bromide, and Chloride.

When these three salts are combined together we have spectra which are very similar to the spectra produced on iodide and chloride, or iodide and bromide, with a prolongation towards the red.

Concluding Remarks.

In a paper read, in 1880, before the Photographic Society of Great Britain, I recommended the addition of a small quantity of iodide to the bromide used in the preparation of gelatine emulsion. On carefully examining spectra photographed on such plates (having $\frac{1}{12}$ part of iodide to $\frac{11}{12}$ of bromide) I find traces of the loss of sensitiveness about G. I stated also that addition of iodide diminished the sensitiveness of the bromide to the red rays; an examination of curves given for the mixtures of bromide and iodide of silver bears out my statement.

It will be noticed that I have not touched upon organic sensitisers of the haloids, prepared with an excess of silver and then washed, and such sensitiser applied. I have only treated of the haloids themselves, endeavouring to eliminate every extraneous effect which would modify the action of the spectrum. I purpose in a subsequent communication to enter into this part of the subject.

VI. "On a New Electrical Storage Battery." By Henry Sutton (Ballarat, Victoria). Communicated by The President. Received December 10, 1881.

The great utility of some thoroughly practical method of conserving electric force has caused a great deal of attention to be applied to the subject; no system of electric supply can be considered as perfect until some means is used to so store the force generated that it may be drawn off equally and regularly, and this whether the generator be on or off. If we take, as an example of electric supply, the present systems of electric lighting, it is at once seen, should an accident or stoppage take place in the machinery generating the current, the whole of the apparatus such as lamps or motor-machines are influenced; should there be a reservoir of electricity between the generator and the apparatus of whatever sort for utilising the force this inconvenience would not occur.

All the present systems of storing electricity depend on certain chemical changes produced by electrolysis.

I have gone through a long series of experiments on storing electricity and made many forms of cells, one being a porous pot containing dilute hydric sulphate and a sheet of lead, in an outer vessel containing a sheet of lead in solution of acetate of lead, the plate in the porous pot being made the positive electrode; this cell had the power of storing electricity, by peroxidising the positive electrode, and depositing from the acetate of lead solution metallic lead on the negative electrode, the hydrogen having combined to form acetic acid. On discharging the peroxide is reduced, and the oxide formed during discharge on the other plate dissolves in the acetic acid, forming the original solution of acetate of lead; by this means I eliminated the injurious effects of the hydrogen on charging.

During my experiments I found that red oxide of lead is a very bad conductor of electricity, and the peroxide a good conductor. I also discovered that by amalgamating lead plates with mercury a marked increase was immediately manifest in polarisation effects, the plates becoming more uniformly and rapidly peroxidised when used as positive electrodes, and local action entirely disappearing. These mercury amalgamated plates at once gave me an advance of other cells. I used them in many ways, constructing cells in which the positive plate was amalgamated, and the negative coated with red oxide, or with peroxide, produced by treating red oxide with dilute hydric nitrate till the brown precipitate of peroxide fell, the precipitate being washed and painted on the electrode. I also amalgamated the negative electrode simply. I found that in every way positive electrodes amalgamated produced the best results. I also made cells in which either peroxide or red oxide was formed into a porous conglomerate, using the conglomerates as electrodes, immersed in dilute hydric sulphate. I constructed cells with parallel plates, red oxide or peroxide being filled in between the plates; in this experiment red oxide is useless and peroxide efficient. In all these experiments I succeeded in storing electricity to different extents.

Having thoroughly satisfied myself that positive electrodes amalgamated with mercury were the best, I investigated the behaviour of various forms of negative electrode, having in view the conservation of the hydrogen; this I thought to do by occluding the hydrogen in suitable electrodes, as spongy platinum or metallic palladium; but as both these methods would be useless owing to expense I did not even experiment on them.

I further thought of having negative electrodes, whose oxides should be soluble in the solution, and which could be redeposited from the solution, or of having metallic solutions from which metal could be deposited, the resulting solution being such that should, on the oxidation of the deposited metal, combine with the oxide and again form the original solution.

I thought that success in this manner would result in a powerful and constant source of stored energy, the cell would not polarise itself during discharge, as is the case in both Planté and Faure cells; in these cells the peroxide formed by the discharge produces a contrary electromotive force.

Experimenting from this train of thought, the results I have obtained are such as to have an important practical bearing on the future of electric work.

The experiments comprised amalgamated lead as a positive electrode with negative electrodes composed of either zinc, iron, or copper, in each case the solution between the electrodes being a salt of the metal composing the negative electrode. With zinc, sulphate of zinc was the solution; with iron, sulphate of iron; and with copper, sulphate of copper. In all these cases the results were not only far more powerful than with any form of cell I had previously devised, but also very constant, the polarisation lasting many times longer than in any other form of cell. The cell with zinc negative electrode I discarded, owing to the necessity there would be to keep the zinc plate amalgamated to prevent local action; the iron negative electrode was set aside owing to the iron oxidising when the cell was not in use. The cell having a negative electrode of copper, a positive electrode of lead amalgamated with mercury and a solution of cupric sulphate, I have adopted as a thoroughly economical, lasting, and practical form of storage reservoir. The chemical changes in this cell are exceedingly interesting and beautiful, the cell being composed of a sheet of lead cleaned with dilute sulphuric acid and amalgamated thoroughly with mercury, and a sheet of thin copper a little shorter; the two sheets are perforated with a number of holes and then rolled in a spiral, separated by rubber bands cut every five inches, the holes in plates and cuts in rubber bands being to allow free circulation of the solution (the short plate being uppermost before rolling). This combination is immersed in a solution of cupric sulphate, and the amalgamated lead plate made the positive electrode of a suitable source of electricity, the chemical action being that the oxygen of the decomposed solution combines with the lead, forming a perfectly even coating of the insoluble peroxide, the hydrogen replacing the copper of the solution, and the copper being deposited in the metallic state on the negative electrode. As the decomposition of the cupric sulphate proceeds the solution gradually loses its azure blue colour, becoming more acid, and finally when the whole of the copper is deposited, we have the solution colourless and transformed into hydric sulphate and water, the positive electrode peroxidised and copper deposited on the negative electrode. During discharge the peroxide is reduced and the copper element oxidised, the oxide combining with the acid and forming cupric sulphate, the solution returning to its original colour. This change of colour forms a beautiful means of telling when the cell is charged; it is a veritable charging gauge. The power of this cell is very great and very constant, it can be made to last for hours, the time being dependent on the quantity of cupric sulphate decomposed.

I have, by the decomposition and recomposition of one pint of cupric sulphate, obtained over two hours' effective work in heating to a red heat one inch of No. 28 iron wire, the cell measuring internally 4 inches deep and 4 inches diameter.

I constructed cells with free crystals of cupric sulphate suspended in the solution, and found that the presence of free crystals prevented the oxidation of the amalgamated lead electrode, it being essential that the solution become slightly acid before the peroxide will form. The cell during charging gives out a peculiar rattling noise, which I consider due to the deposition of copper on the negative electrode altering the form of the spiral.

A practical form of cell for storing purposes ought to be made, by fixing a series of amalgamated lead plates in a box in grooves, as in Cruikshank's trough battery, filling the interval between the plates with solution of cupric sulphate, and passing a current through of sufficient tension to overcome the contrary electromotive force of the series, the positive sides of the plates being peroxidised and copper deposited on the negative sides. I have two boxes on this plan, each containing twenty-five plates, the total being equivalent to fifty cells. By this means batteries of great tension can be charged from thirty Bunsens. A number of twenty-five plate boxes can be coupled for quantity in charging, and for tension during discharge. Twenty such boxes, one foot square, internal measurement, will give in series a battery of 500 pairs of one foot square plates.

It will be seen from the foregoing that this method of conserving energy has a wide field before it, and as it will benefit fellow-workers in science, placing in their hands a means of experimenting with powerful electric currents, I give it without reservation, freely and untrammelled by patent rights, for their use.

December 22, 1881.

THE PRESIDENT in the Chair.

The Right Hon. Sir William George Granville Venables Vernon Harcourt, Knt., was admitted into the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On the Germinal Layers and Early Development of the Mole." By WALTER HEAPE. Communicated by F. M. BALFOUR, F.R.S. Received November 30, 1881.

The following is a note on some investigations which I have been carrying on by the kindness and with the help of Mr. Balfour, in the Morphological Laboratory, Cambridge, upon the origin and formation of the germinal layers in mammals, more especially in the mole (*Talpa Europea*). I hope shortly to be able to give a more complete account.

In the communication the following subjects are dealt with:—

(1.) The origin of the epiblast.

(2.) The mode of development of the mesoblast.

(3.) The structure of the neurenteric canal.

(4.) The relations of the mesoblast and the hypoblast to the notochord.

Recent investigations have left the earlier phases of mammalian development in some confusion, it may therefore be advisable briefly to mention the more important views which are entertained on this subject.

Professor Edward van Beneden, in a paper entitled "La formation des feuillets chez de Lapin" ("Archives de Biologie," vol. i, Part 1, 1880), gives an account of the segmentation of the ovum of that animal, and states that during segmentation a differentiation of the segmentation spheres into two layers is established, the one of which grows over and encloses the other, giving rise in this manner to what Van Beneden calls a metagastrula. The outer of these two layers he terms ectoderm and the inner entoderm, names which seem to me, for reasons which will appear in the sequel, to be misleading, and for which I propose to substitute the terms outer and inner layers respectively.

Subsequently, according to Van Beneden, a cavity, the blastodermic cavity, is developed between the outer and inner layers of cells; the cells of the former layer become flattened and multiply, and form the wall of the so-called blastodermic vesicle; at the same time the blastodermic cavity is enlarged, while the inner layer remains as a rounded mass of cells attached to the wall of the vesicle over a small area known as the embryonic area. Van Beneden considers that the outer layer of cells forms the permanent epiblast, both of the embryonic area and of the blastodermic vesicle, while the inner mass of cells breaks up into two layers, a lower single layer of flattened cells, the hypoblast, and a layer of cells which he calls the mesoblast, lying between the hypoblast and the epiblast of the embryonic area.

Professor Kölliker, on the other hand, writing in the "Zoologischer Anzeiger" (Nos. 61 and 62, vol. iii, 1880), "Die Entwicklung der Keimblätter des Kaninchens," does not dispute the presence of Van Beneden's epiblast, hypoblast, and mesoblast, in the stage of development described above, but states his agreement with an earlier view of Rauber, that in the region of the embryo the outer of these layers disappears, while the whole of the middle layer becomes converted into the epiblast of the embryonic area; the epiblast of the remainder of the vesicle, however, he considers is formed from part of the original outer layer of cells. The mesoblast owes its origin, in his opinion, wholly to a budding from the epiblast of the primitive streak.

Professor Lieberkühn published in Marburg, in 1879, in a paper "Ueber die Keimblätter der Säugethiere," the results of his researches upon the dog and mole, in which he states that the epiblast of the embryonic area is derived from the greater part of the primitive inner mass of cells (that portion in fact forming Van Beneden's mesoblast), together with the part of the original outer layer of cells which overlays the inner mass; the hypoblast he derives from the inner mass of cells, while the mesoblast he believes to be formed from both epiblast and hypoblast, in the region of the primitive streak.

I myself have been fortunate enough to secure a fairly complete series of mole embryos ranging from an early appearance of the blastodermic cavity until the formation of the medullary groove; an examination of which leads me, in the main, to agree with Lieberkühn's account of the development of the embryonic layers of that animal.

I have not been able to follow completely the course of segmentation, nor have I been able to trace a differentiation of the segments into two layers, an outer and an inner, though there appears to be no doubt, on account of the arrangement of the spheres in a somewhat later stage, that Van Beneden's description of a fully segmented ovum is substantially correct.

The earliest specimen of an ovum in my possession after the completion of segmentation is similar to that figured in Van Beneden's paper (*loc. cit.*), Plate IV, fig. 6, III, and in Lieberkühn's paper (*loc. cit.*), fig. 1.

The ovum consists of an outer layer and an inner mass of cells, between and partly separating which is a cavity. The outer layer has the form of a sphere of somewhat flattened cells, while the inner mass is composed of irregularly polygonal cells; these two are attached together for a small area, elsewhere they are separated by a cavity, the blastodermic cavity, which is seen in optical section as a crescent-shaped space partially surrounding the inner mass of cells. The diameter of this ovum measures ·11 millim., and that of the inner mass of cells ·06 millim. A thick zona invests the ovum.

Upon the formation of the blastodermic cavity, the ovum may be called the blastodermic vesicle.

The vesicle becomes enlarged, and I am inclined to believe, that during the enlargement, the cells of the inner mass assist in the formation of the outer wall of the vesicle, since in various vesicles of about ·2, ·25, ·3, ·38 millim. diameter, the diameter of the inner mass, which is of an approximately spherical shape, is less, being respectively ·04, ·04, ·04, ·05 millim., than in the youngest vesicle, measuring as stated above, ·11 millim. in which the inner mass is ·06 millim. diameter.

Sections through a vesicle measuring ·25 millim. diameter (the inner mass measuring about ·04 millim.) show the outer layer to be composed of greatly flattened cells closely applied to the zona, which is now much thinner, owing to the expansion of the vesicle, while the inner mass in the form of a solid mass of irregularly rounded cells is attached to the outer layer for a small circular region, which I shall speak of as the embryonic area.

As the vesicle enlarges, the inner mass of cells slightly flattens out and widens at the same time, so that the embryonic area becomes enlarged.

In a vesicle ·44 millim. diameter, the inner mass of cells is seen to be commencing to divide into two layers, and in a vesicle ·57 millim. in diameter, in which the inner mass is ·08 millim. in diameter, this division is completed, and a layer composed of a single row of slightly flattened cells is separated off from and underlies the main portion of the inner mass of cells; this layer is the hypoblast. The main portion of the inner mass of cells is undergoing at the same time a change in structure, inasmuch as some of the polygonal or rounded cells of which it has hitherto been composed now become elongated and columnar.

The hypoblast in an oval blastodermic vesicle of about ·88 millim. by ·81 millim., is still formed of slightly flattened cells beneath the embryonic area, but it has grown and extended beyond that area, so that its outer part lies beneath and in close contact with the outer layer of the blastodermic vesicle; the cells of this portion of the hypoblast are wide and much flattened, and their nuclei stain deeply with hæmatoxylin.

A cavity appears about this stage of development in the region of the embryonic area between the flattened outer layer and the inner mass, the cells of the latter having now largely become columnar. In the vesicle last mentioned (·88 millim. by ·81 millim.), nearly the whole of the inner mass has become transformed from a rounded mass of polygonal cells into a concave plate of columnar cells, forming the floor of a cavity which is roofed over by the cells of the outer layer of the blastodermic vesicle. In this cavity a few cells are placed, which are connected with the outer layer or inner mass, or with both of these, by means of protoplasmic processes; I believe these cells to be cells of the inner mass which have not yet become columnar.

Lieberkühn states that some of the cells of the inner mass grow round and above the cavity just described, which thus comes to lie within the inner mass. The specimens from which he derives his opinion however, were, I believe, preserved in Müller's fluid. I have myself seen a similar apparent arrangement in such preparations, which upon comparison with sections of vesicles of similar ages prepared in picric acid, appear to me to bear a different interpretation, the layer of cells above the cavity being formed of flat outer layer cells with a few more or less isolated cells of the inner mass.

In a vesicle of about ·97 millim. diameter, the inner mass of cells has still the form of a concave plate composed of two or three layers of for the most part columnar cells: the flattened cells of the outer layer remain, as in the previously described specimen, closely attached to the zona, and the cells lying in the cavity are fewer, while some of them appear to have been drawn on to the concave plate and transformed into columnar cells. Cells in a transition stage may be seen on the surface of the plate.

At a later stage the concave plate extends itself, the curvature becoming less, and eventually approaches to and finally comes into contact with the flat cells forming that portion of the wall of the vesicle which in the previously described specimens lay above the plate; the flattened cells of this part soon become columnar, and the fusion between them and the plate below becomes complete.

Somewhat prior to this stage, the edges of the plate become continuous with the outer layer of the wall of the vesicle beyond the region of the embryonic area.

Thus, the greater part of the inner mass of cells, as Lieberkühn correctly states, combines in the form of a plate of more or less columnar cells with that part of the flat outer layer of cells which immediately overlies it, to form a plate of columnar cells two and three rows deep; this plate is the epiblast plate of the embryonic area, the remainder of the outer layer of cells forming the epiblastic wall of the blastodermic vesicle.

The portion of the inner mass of cells which was separated off from the main mass as the hypoblast still forms only a single row of somewhat rounded cells, the central part of which underlies the embryonic area, while the peripheral part continually extends as a layer of flattened cells along the inner aspect of the epiblastic wall of the remainder of the blastodermic vesicle.

In concluding this portion of my subject I may add, in support of what I believe in harmony with Lieberkühn to be the origin of the true epiblast of the embryonic area in the mole, that in the course of my work on this subject, carried on since the investigations of Mr. Balfour and myself, published in the second volume of Mr. Balfour's "Comparative Embryology," I have obtained from an embryo rabbit of six days four hours old, sections which appear to me conclusively to confirm the results at which we before arrived, namely, that the epiblast plate of the embryonic area is derived (as in the mole) conjointly from the at first flattened cells of the primitive outer layer (called by Rauber and Kölliker "Deckzellen," and stated by those observers to disappear from the embryonic area), and from the larger portion of the primitive inner mass of cells (held by Van Beneden to be the true mesoblast, and stated by Kölliker alone to form the epiblast plate). In the sections of this embryo the cells of the already described primitive outer layer are seen in a transition stage, being wedge-shaped and prolonged in between the cells of the inner mass.

At the stage of growth now arrived at the blastodermic vesicle may be considered to consist of an embryonic and a non-embryonic portion. A surface view shows the embryonic area to be in the form of a more or less circular opaque disk. The wall of the vesicle consists of a two-layered and a single-layered portion; the latter, formed of epiblast, alone comprises the portion of the wall opposite to the embryonic area, while the former, consisting of epiblast and hypoblast, forms the embryonic area and the part of the vesicle immediately adjoining it.

In the course of further growth the vesicle greatly enlarges, and the zona becomes much attenuated, affording but little support to the now also exceedingly thin and delicate wall of the vesicle; it therefore becomes difficult to obtain specimens in good preservation.

In the earliest specimen of this stage which I possess the embryonic area is oval, measuring ·74 by ·48 millim. In a surface view a dark line or band is seen to run along the centre of the hinder third of the area. This is the well known primitive streak; it is narrow anteriorly, while posteriorly it becomes broader, and finally behind takes up nearly the whole breadth of the embryonic area; it is due to the presence of a third layer of cells, the mesoblast, between the epiblast and hypoblast. Transverse sections of this embryonic area show the major portion in front of the primitive streak to be composed (1) of a plate of epiblast formed of two or three rows of columnar cells, and (2) of a single layer of rounded hypoblast cells somewhat flattened towards the edge of the area. Immediately in front of the primitive streak there appears, extending entirely across the area, a layer of mesoblast, which is not connected with the epiblast, but is so intimately united with the hypoblast in the middle line, that the two layers cannot there be clearly distinguished, though towards the periphery of the area they are quite distinct. A section taken through the anterior end of the primitive streak discovers a narrow band of epiblast cells in the middle line, giving rise by budding to a layer of mesoblast which extends laterally to the edge of the area, and in each section following (*i.e.*, towards the hind end of the primitive streak) the budding epiblast appears continually as a wider band until the greater part of the whole breadth of the epiblast plate is concerned in the production of mesoblast. A pit is seen in the epiblast almost at the front end of the primitive streak, and at this point a neurenteric canal will eventually be formed; this structure, hitherto overlooked in mammalian embryos, is identical with the neurenteric canal found in other types of Vertebrata.

The primitive streak grows relatively longer compared with the increase in size of the embryonic area, until in a vesicle, in which the latter measures about ·84 by ·71 millim., the primitive streak reaches along it fully three parts of its length. It is very narrow in front, while behind it occupies the whole breadth of the embryonic area. In sections of the region in front of the primitive streak there is present a layer of cells several rows thick immediately underlying the epiblast plate. In the seven anterior sections this layer is seen beneath the epiblast, as a mass which cannot be resolved into hypoblast and mesoblast; for about three following sections, placed immediately in front of the primitive streak, the layer is clearly composed of (1) a layer of flattened hypoblast below, and (2) a layer of mesoblast above. The mesoblast in the axial line is thickened in the last two of these sections, and posteriorly joins the anterior wall of the neurenteric canal, while the hypoblast extends as a distinct layer below the anterior end of the primitive streak. It appears highly probable that the whole layer in the seven sections at the front end of the embryonic area, is the hypoblast originally present there engaged in the act of budding off mesoblast, as Balfour believes to be the case with regard to a similarly situated portion of the hypoblast in the chick ("Comparative Embryology," vol. ii, p. 129 *et seq.*). In the three following sections where distinct layers of mesoblast and hypoblast are found, the whole of the mesoblast, with the exception of the cells forming the central thickening in the second and third sections, has, I believe, a similar origin, and may be distinguished by the form and appearance of its cells from the mesoblast of the primitive streak. The mesoblast derived from the hypoblast may be called hypoblastic mesoblast; it joins the mesoblast of the primitive streak as the latter grows forward, and the two become indistinguishable.

The primitive streak presents in section a similar appearance to that of the embryo last described; a groove—the primitive groove—is, however, present along its upper surface. The position of the future neurenteric canal is indicated by a pit in the epiblast as in the specimen described above.

At a slightly later stage the embryonic area being 1·17 by ·81 millim., the condition of the layers is much the same. A neurenteric canal now perforates the whole thickness of the blastoderm at the front end of the primitive groove. The upper opening of this canal, which is longer than the lower opening, has the appearance of a slit with its anterior wall sloping obliquely backwards; this wall is continuous with the thickening of mesoblast cells in the axial line which I described in the last stage. The first traces of the amnion are now visible, as a fold of the epiblast round the whole circumference of the embryonic area; at the posterior end the folds of the two sides meet to form a hood, covering the hinder part of the area, but anteriorly I have been unable to determine the extent of their growth.

In the surface view of an embryonic area measuring ·97 by ·79 millim. in diameter, a band of a lighter shade than the remainder is to be seen in the front part of the long axis of the area, its posterior end adjoining the anterior end of the primitive streak; the latter occupies the hinder third of the area, and where it joins the light-coloured band a pit, the upper opening of the neurenteric canal, is distinctly to be seen surrounded by a dark rim.

In transverse section the light-coloured band is seen to be caused by a diminution in thickness of the epiblast plate and of the mesoblast in the middle line. The epiblast of this region is bent inwards to form a groove, the medullary groove; it is wide and shallow throughout, and the cells forming it are not more than two rows deep, while the remainder of the epiblast plate, except at the extreme edge, is three cells deep.

Anterior to the medullary groove a continuous layer hardly differentiated into mesoblast and hypoblast underlies the epiblast plate. In the region of the medullary groove an axial strip of the cells underlying the epiblast exhibits no division into hypoblast and mesoblast; this portion, though partially separated from the lateral masses of mesoblast, is still connected with them however on each side by a narrow neck of cells, and is also directly continuous laterally with the hypoblast. The lateral hypoblast is quite distinct from the superjacent lateral masses of mesoblast. The axial strip of cells underlying the medullary groove (thus shown to be continuous with both the mesoblast and the hypoblast) may be regarded as the commencing notochord.

The neurenteric canal does not any longer perforate the blastoderm, its upper part alone remaining, which is surrounded by a thick mass of mesoblast, causing the dark rim seen in the surface view round the pit. Its anterior wall is connected with the axial mass of cells underlying the medullary groove, while its hind wall forms the front end of the primitive streak.

The surface view of a somewhat older specimen, 1·5 millims. by ·81 millim. diameter, shows the medullary groove relatively much longer and more clearly defined. Anteriorly it reaches near to the edge of the embryonic area.

In section it is seen to be shallow at each end, but is much deeper and narrower towards the middle of the embryonic area. Its walls, at the anterior end, are but slightly less thick than the remainder of the epiblast plate, but in the deeper part of the groove become considerably thinner. Where the groove is deepest the notochord and adjacent parts form a well-marked projection into the blastodermic cavity beneath.

The rudimentary notochord has now extended beyond the anterior end of the medullary groove, and its relations to the adjacent layers are, for the most part, the same as in the previously described specimen. In front of the medullary groove it is composed of a single row of somewhat columnar cells, continuous laterally with both mesoblast and hypoblast; below the anterior more shallow part of the medullary groove similar relations exist, towards its middle and deeper part however, where the lateral mesoblast is commencing to form protovertebræ, the notochordal cells, still in the form of a single row, are connected solely with the lateral plates of hypoblast, while further backwards, where the medullary groove becomes again more shallow, the cells of the notochord become more than one row deep, and are again continuous both with the lateral mesoblast and hypoblast. The notochord, continually thickening towards its hinder extremity, terminates by fusing with the anterior wall of the neurenteric canal. The latter structure is now open above on the floor of the posterior end of the medullary groove, and extends downwards into the cells beneath, though it no longer perforates the hypoblast, which is, however, somewhat involuted, and indistinguishably fused with the mesoblast in the median line.

Briefly to recapitulate, I have attempted to show :—

(1.) The epiblast of the blastodermic vesicle owes its origin as well to the inner mass of segmentation spheres as to the outer layer of segments. It appears to originate in two ways:

(*a.*) In an early stage of development (in the mole) probably by the cells of the inner mass being directly transformed into part of the wall of the blastodermic vesicle.

(*b.*) In a later stage (mole and rabbit) by the transformation of the rounded cells of the inner mass into a plate of columnar cells, which joins the part of the outer layer lying immediately above it to form the epiblast plate of the embryonic area.

(2.) The mesoblast in the mole is formed in two portions :—

(*a.*) A larger portion which has its origin in the primitive streak.

(*b.*) A smaller portion which is derived from the hypoblast situated in front of the primitive streak.

I have been unable to distinguish where the latter, or hypoblastic mesoblast, comes into contact with the mesoblast of the primitive streak, and what part these respective layers take in the future development of the embryo.

(3.) A neurenteric canal is present in the mole similar to that formed in other types of Vertebrata, first appearing as a pit at the anterior end of the primitive streak, while in later stages it perforates the floor of the hinder end of the medullary groove.

I may here add that I have also found in a seven days' rabbit embryo a rudimentary neurenteric canal in the form of a shallow pit in the epiblast at the front end of the primitive streak.

(4.) The notochord is formed of an axial strip of cells, which underlies the epiblast of the medullary groove, and which either never become divided into mesoblast and hypoblast, or in which such a division, if it does take place (as appears not impossible), is very soon lost. This strip of cells is originally continuous laterally with both mesoblast and hypoblast, but as the lateral mesoblast becomes converted into definite vertebral plates the connexion is lost.

There can, I believe, be no doubt of the connexion of the lateral hypoblast and mesoblast with the notochordal cells in the mole; in the rabbit I am inclined to believe that a similar connexion is present, but my evidence on this point is not yet conclusive.

II. "On the Rhythm of the Heart of the Frog, and on the Nature of the Action of the Vagus Nerve." By W. H. GASKELL, M.D. Cantab. Communicated by Dr. MICHAEL FOSTER, Sec. R.S. Received December 8, 1881.

(Abstract.)

The method of investigation employed by the author is as follows:— The heart with the vagus nerve intact having been removed from the body together with a portion of the œsophagus, a thread is tied to the very apex of the ventricle and another to the loose flap which is disclosed at the junction of the two auricles when the two aortic trunks are cut away. The piece of the œsophagus removed with the heart is held firmly in a suitable holder and the heart suspended between two horizontal levers by means of the two threads which are attached to the auricles and ventricle. Between the two levers a clamp is placed, the edges of which can be approximated to any degree by means of a fine micrometer screw; the two limbs of this clamp are placed one on each side of the suspended heart, and by means of the micrometer screw, the tissue between the two edges can be simply held firm or compressed to any extent required. In this way, with the clamp in the auriculo-ventricular groove, the beats of both auricles and ventricle are registered simultaneously and separately; the contractions of the auricles pull the upper lever downwards, those of the ventricle the lower lever upwards. Similarly by varying the position of the clamp the contractions of any two adjacent portions of the heart can be studied, as for example, sinus and auricles, base and apex of the ventricle, &c.; heat, cold, and poisons can be applied to the tissue on the one side of the clamp and not on the other; and under all these various conditions the effects of stimulation of the vagus can be observed.

The paper is divided into two parts: Part I, on the rhythm of the heart; Part II, on the action of the vagus nerve.

In Part I reasons are given for the view that discrete impulses pass from the motor ganglia to the muscular tissue, that, therefore, the normal rhythm of the heart is dependent upon rhythmical discharges from the motor ganglia, and is not due to the production by the cardiac muscle of rhythmical results from a constant stimulation. This follows from the fact that any influence which, when applied to the auricles and sinus alone, causes an alteration in the rhythm of the auricles, affects the rate of the ventricular beats synchronously; while the same influence applied to the ventricle alone, causes no alteration in the rhythm of the auricles or in the synchronism of the ventricular with the auricular beats. Thus heat applied to the ventricle alone does not alter its rhythm although it reduces the force of

its contractions; while on the other hand, when applied to the auricles and sinus alone, it quickens the rhythm most markedly. Cold, atropin, muscarin, all slow the rhythm when applied to auricles and sinus, but cause no alteration of rhythm except in extreme doses when applied to the ventricle alone.

The author then proceeds to consider the conditions which are necessary in order that each one of these impulses should produce a contraction, and concludes that a due relation must exist between the strength of the impulse and the excitability of the tissue in order to obtain this result.

By a comparison of the rate of the contractions of the auricles with those of the ventricle, it is found that the ventricle can be made to beat synchronously with every second, third, fourth, or more auricular beats, or to cease from beating altogether by increasing the compression of the clamp in the auriculo-ventricular groove or by heating the sinus and auricles alone without heating the ventricle. The commonest and most permanent effect is to make the ventricle beat synchronously with every second auricular beat.

This same want of sequence between the ventricular and auricular contractions can also be obtained by the application of various poisons to the ventricle alone. A marked difference however exists between the two cases. In the first case, when the ventricle is made to beat with half-rhythm by tightening the clamp, or by heating the auricles and sinus, its contractions are those of a strong vigorous muscle, and are more powerful than when the ventricle was beating synchronously with every beat of the auricles; on the other hand, the application of poisons to the ventricle does not produce this effect on its rhythm until by the action of the poison the force of the contractions has become greatly reduced.

For this and other reasons given in the original paper, the author concludes that either tightening the clamp or heating the auricles and sinus alone diminishes the strength of the impulses passing to the ventricular muscle, and so causes the half-rhythm observed; while various poisons applied to the ventricle alone produce the same effect by diminishing its excitability, without affecting the strength of the impulses.

The conclusions arrived at in Part I can be summed up in the following propositions:—

1. The rhythm of the heart is caused by discrete motor impulses passing to the muscular tissue from certain motor ganglia.

2. In order that each one of these impulses may produce a contraction of the ventricle a due relation must exist between the strength of the impulse and the excitability of the ventricular muscle.

3. When each impulse is inefficient to cause a contraction of the ventricle, the ventricular muscle has the power of summing up the

effects of two or more of these inefficient impulses, and so continues to beat rhythmically though no longer synchronously with every impulse.

4. The most satisfactory explanation of this summation process is as follows:—Every impulse which is inefficient to produce a muscular contraction increases the excitability of the muscle, and therefore makes it easier for a second similar impulse to cause a contraction.

5. The impulses can be made inefficient to produce contractions synchronous with them by lowering sufficiently the excitability of the ventricle, as is seen in the action of poisons, even although the rate and strength of the impulses remain unaltered.

6. The impulses can also be made inefficient, when the excitability of the muscle is unchanged, by diminishing the strength of the impulses, as is seen in the effects of compressing the tissue between the ventricle and the motor ganglia, or of heating the auricles and sinus without heating the ventricle.

7. There is a limit to the extent to which a series of inefficient impulses can raise the excitability of the muscle, so that the ventricle can remain absolutely quiescent, even although the impulses still pass to it, when those impulses are sufficiently weakened.

In Part II the action of the vagus nerve is considered, and it is shown that its stimulation produces a most marked effect upon the force of the contractions, both of auricles and ventricle, entirely independent of any alteration of rhythm. The curves obtained can be classified under the three following types:—

1. Complete quiescence of both ventricle and auricles, followed by contractions which at first are scarcely visible, but which rapidly increase in size, until at the maximum they are much greater than before the stimulation of the nerve. From this maximum they very gradually decrease, until the original size of contraction is again reached.

2. During the stimulation no quiescence of either ventricle or auricles, but simply a diminution of the size of the contractions, followed by a rapid and marked augmentation of the contractions beyond the original height, and then a slow gradual diminution to the size obtaining before the nerve was stimulated.

3. No primary diminution, but from the commencement of the stimulation the beats increase in size, and after a time gradually return again to the original size.

Between these three types every conceivable variation may occur, so that a series of curves may be selected in which no line of demarcation can be drawn between complete primary quiescence, or to use the usual term, inhibition, on the one hand, and a simple primary augmentation of the size of the contractions on the other.

These curves alone show that the vagus is able to cause a standstill by diminishing the force of the contraction down to quiescence; this is further shown by the fact that standstill of the ventricle alone can occur while the auricles are beating with accelerated or unaltered rhythm, but diminished force, or even when from the commencement of the stimulation the force of the auricular contractions is increased.

This same gradation of effect, as the result of the stimulation of the nerve, from absolute standstill to a simple primary augmentation, is seen more or less clearly in the course of each separate experiment; the stimulations that occur immediately after the suspension of the heart are much the most likely to produce standstill; later ones to cause primary diminution followed by augmentation, and finally augmentation alone.

The power of diminishing the contractions to standstill appears to last longer after the heart has been suspended at some times of the year than at others.

The conclusion is drawn that the variations in the effects produced by stimulation of the vagus on the force of the contractions are dependent essentially upon the condition of the nutrition of the heart; and possibly for the same cause the vagus tends to lose all power of producing slowing after the heart has been suspended in the apparatus, for in most cases acceleration only is seen, although slowing occurred on stimulation before the heart was cut out, and apparently slowing is more likely to occur immediately after the suspension of the heart than later.

The action of the vagus upon the muscular tissue is not only shown by its effect on the size of the contractions, but also by its influence on the excitability and tonicity of the ventricular muscle.

When by tightening the clamp the ventricle is made to beat synchronously with every second auricular beat, stimulation of the nerve may cause the ventricle during the stimulation to beat synchronously with every third, fourth, or more auricular beats; and the same alteration in the relation between the rhythm of the two parts above and below the clamp is seen in the case of the contractions of the apex and base of the ventricle, when the clamp is placed midway across the ventricle.

Also, when the ventricle is beating with half-rhythm from the action of the clamp, stimulation of the nerve may make it beat synchronously with every beat of the auricles for a definite time; and when the ventricle is not beating, either in consequence of tightening the clamp, or of heating the auricles and sinus, then vagus stimulation may cause a series of contractions synchronous with those of the auricles.

These experiments are to be explained on the supposition that the vagus stimulation diminishes the excitability of the ventricle at one time and increases it at another, and it is also shown that the times of this diminution and increase correspond respectively to the periods when the vagus causes a diminution and increase of the size of the contractions.

The action of the vagus upon the muscular tissue of the ventricle is further shown by its power of removing the inequalities in the size of the ventricular contractions, when as often happens, the ventricle is beating with alternately strong and weak contractions.

Stimulation of the nerve causes this inequality to disappear when it increases the force of the contractions, and to reappear again when it diminishes that force.

The effect of stimulation of the vagus upon the tonicity of the ventricle was studied by the method described elsewhere,* and the author shows that the relaxation between the beats of the ventricle is increased during the stimulation of the nerve, even although the rate of rhythm is not made slower.

The conclusion therefore is drawn, that stimulation of the vagus acts upon the muscular tissue of the ventricle in such a way as to diminish its excitability and lower its tonicity, when it reduces the force of the ventricular contractions, while it increases its excitability and possibly also increases its tonicity when it augments the contraction force.

Finally, it is shown that atropin removes the whole action of the vagus stimulation, and the effects of the local application of curare, muscarin, and atropin are described and discussed.

In conclusion, the author sums up the results of these experiments, and suggests that a series of formative processes are going on in both the muscular tissue and the motor ganglia of the heart, similar to those which occur in gland-cells, and that the vagus produces all its effects by increasing the activity of these processes and not because it contains a multiplicity of fibres, each of which possesses a different function.

III. "On Melting Point." By Edmund J. Mills, D.Sc., F.R.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. Received December 6, 1881.

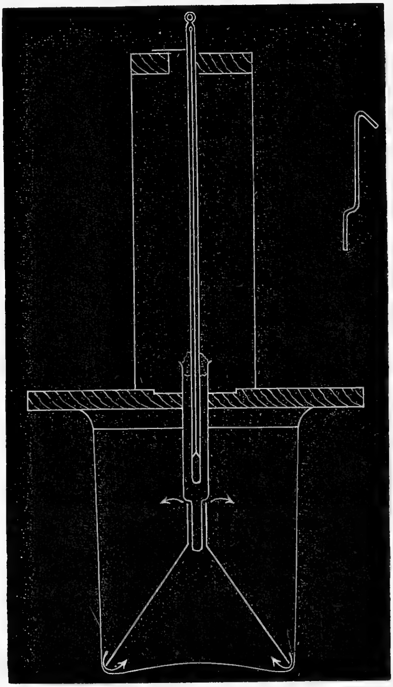
(Abstract.)

The investigation, of which the memoir contains an account, was undertaken in order to determine, with considerable accuracy, the

* "Journal of Physiology," vol. i, p. 452.

temperature at which certain organic substances pass from the solid to the liquid state.

The apparatus, of which an engraving, on a scale of one-fourth,* is given below, consists of a bath nearly filled with oil of vitriol. In this is



inserted a glass funnel, having on its lower edge six equidistant semicircular cuts of about 5 millims. radius, and, at the end of the neck, four of the same. A thin test-tube, resting freely on the funnel, contains a bath of paraffin oil, in which the thermometer's bulb is centrally placed; against the bulb, in a little tube separately represented, is fixed the substance whose melting point is to be determined. When the large bath is heated, constrained and regular convection takes place in the liquid; the effect upon the thermometer is such as to cause the mercury to rise with very great steadiness.

A preliminary series of researches in thermometry has enabled me to give a series of results completely corrected, and in terms of the air thermometer.

* The portion above the cover of the bath is not to scale.

Substance.	Weighted, mean.	After Poggendorff's correction.	Air therm.
Toluidine	42·765	42·700	42·890
Nitrophenol (*a*)	44·270	44·205	44·392
Nitrotoluol	51·305	51·239	51·407
Dichlorobenzol	52·723	52·657	52·821
Nitronaphthalin	56·175	56·110	56·261
Dinitrophenol (*a*)	61·778	61·714	61·843
Monobromaniline	61·806	61·742	61·871
Dinitrotoluol (*a*)	69·211	69·154	69·252
,, (*b*)	69·571	69·514	69·610
Monochloraniline	69·667	69·610	69·706
Dinitrobromobenzal	70·598	70·542	70·634
Trichloraniline	77·052	77·004	77·068
Dibromaniline	78·821	78·776	78 833
Trinitrotoluol	78·841	78·796	78·853
Naphthalin	80·061	80·018	80·070
Trinitrotoluol (M)	80·524	80·481	80·532
Nitrodibromobenzol	83·490	83·452	83·492
Dibromobenzol	87·037	87·007	87·035
Dinitrobenzol	89·718	89·693	89·712
Nitrophenol (*b*)	111·413	111·448	111·455
Dinitrophenol (*b*)	111·579	111·614	111·621
Tribromaniline	116·247	116·298	116·319
Trinitrophenol	121·082	121·151	121·194

Mean probable error of a result, in terms of the air thermometer, 0°·015.

The method of purification adopted was based upon what may be termed the principle of *multiple successive solvents*. It is well known that small quantities of impurities are prone to cling to substances with great tenacity; but the observation has most frequently been made in connexion with a single solvent. One can readily conceive that the tenacity with which a given trace of a foreign body is held, under such circumstances, may be in effect constant. If, however, we now transfer the mixture to a second solvent, it may be presumed that the trace will be in a condition of altered adhesiveness, and may be much more readily separable. In accordance with this principle the substances were crystallised from two solvents at least, and the constant melting points of successive fractions recorded. After every fractional crystallisation, pressure was had recourse to for about twelve hours.

A glance at the table shows that, on the whole, melting point and formula grow together. The following instances of this law (M.P.=*m* Formula) are adduced:—

Substance.	Formula.	M. P.	*m*.
Dichlorobenzol	$C_6H_4Cl_2$=147 ..	52·821 ..	·35933
Bromaniline	C_6H_6BrN=172 ..	61·742 ..	·35971
Trinitrotoluol......	$C_7H_5N_3O_6$=227 ..	80·532 ..	·35477

Here the first pair of values of *m* are almost identical. It is evident, however, that this simple relation does not generally prevail; indeed, in the case of isomeric substances, melting point may alter widely, while additive formula remains constant.

The following are examples of the identification of series by melting point:—

	M. P.		M. P.
α-Trinitrotoluol......	78·853—	α-Dinitrotoluol	69·252=9·601 }
Trinitrophenol.....	121·194—	β-Dinitrophenol	111·621=9·573 }
α-Dinitrotoluol	69·252—	Nitrotoluol	51·407=17·845 }
α-Dinitrophenol......	61·843—	α-Nitrophenol	44·392=17·451 }

The melting points recorded in the memoir are important physical constants, now first determined with a small probable error, and with an apparatus of considerable simplicity. Under no range of ordinary atmospheric pressure or latitude, and in no ordinary interval of time, are these constants likely to become impaired. Hence, if the substances referred to be prepared and preserved with average care, and handled with moderate skill, they constitute in themselves a set of thermometric standards, distributed at mean intervals of about 4° between 42° and 120°. If these substances, or most of them, be at hand, they enable an investigator to at once calibrate and directly refer to the air thermometer any standard mercurial instrument, without the necessary application of any correction whatever.

IV. "Memoir on the Theta-Functions, particularly those of Two Variables." By A. R. Forsyth, B.A., Fellow of Trinity College, Cambridge. Communicated by A. Cayley, LL.D., F.R.S. Received December 9, 1881.

(Abstract.)

The paper of which this is an abstract is divided into four parts, to the whole being prefixed a list of the more important papers dealing with the double theta-functions.

Section I treats of what may be called Rosenhain's theory, and its object is to obtain from a more general basis, and in an easier manner, the results given by Rosenhain in his essay "Mémoire sur les Fonctions des Deux Variables et à Quatre Périodes," which obtained the

prize given by the Paris Academy of Sciences in 1846, and was published in the "Mémoires des Savans Étrangers," tom. xi. Taking as the definition of the general double theta-function

$$\Phi\left\{\begin{pmatrix}\lambda, \rho\\ \mu, \nu\end{pmatrix} x, y\right\}$$
$$=\sum_{m=-\infty}^{m=\infty}\sum_{n=-\infty}^{n=\infty}(-1)^{m\lambda+n\rho}p^{\frac{1}{4}(2m+\mu)^2}q^{\frac{1}{4}(2n+\nu)^2}r^{\frac{1}{2}(2m+\mu)(2n+\nu)}e^{(2m+\mu)\frac{i\pi x}{2\mathrm{K}}+(2n+\nu)\frac{i\pi y}{2\Lambda}},$$

and denoting the product of four functions, in which the characteristic numbers and the variables have the subscript indices 1, 2, 3, 4 respectively, by

$$\Pi\Phi\left\{\begin{pmatrix}\lambda, \rho\\ \mu, \nu\end{pmatrix} x, y\right\}$$

there is investigated, by the guidance of Professor H. J. S. Smith's paper on the Single Theta-Functions in the first volume of the "Proceedings of the London Mathematical Society," the theorem

$$4\Pi\Phi\left\{\begin{pmatrix}\lambda, \rho\\ \mu, \nu\end{pmatrix} x, y\right\}=$$

$$\begin{array}{l|l}
 & +(-1)^{\Lambda'} \\
\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}\\ \sigma, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & \Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}\\ \sigma+1, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
+\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}\\ \sigma, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & +\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}+1\\ \sigma+1, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
+\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}+1\\ \sigma, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & -\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}\\ \sigma+1, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
+\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}+1\\ \sigma, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & -\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}+1\\ \sigma+1, \sigma'\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
 & \\
+(-1)^{\mathrm{P}'}\text{ into} & +(-1)^{\Lambda'+\mathrm{P}'}\text{ into} \\
\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}\\ \sigma, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & \Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}\\ \sigma+1, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
-\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}+1\\ \sigma, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & -\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}\\ \sigma+1, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
+\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}\\ \sigma, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & -\Pi\Phi\left\{\begin{pmatrix}\Lambda, \mathrm{P}+1\\ \sigma+1, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} \\
-\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}+1\\ \sigma, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\} & +\Pi\Phi\left\{\begin{pmatrix}\Lambda+1, \mathrm{P}+1\\ \sigma+1, \sigma'+1\end{pmatrix}\mathrm{X}, \mathrm{Y}\right\}
\end{array}$$

in which

$$2(\Lambda_1+\lambda_1)=2(\Lambda_2+\lambda_2)=2(\Lambda_3+\lambda_3)=2(\Lambda_4+\lambda_4)=\lambda_1+\lambda_2+\lambda_3+\lambda_4=2\Lambda',$$

and similarly for μ, ρ, ν; and

$$2(\mathrm{X}_1+x_1)=2(\mathrm{X}_2+x_2)=2(\mathrm{X}_3+x_3)=2(\mathrm{X}_4+x_4)=x_1+x_2+x_3+x_4,$$

and similarly for the y's. Since the assumption has been made that the sums of the four similarly situated numbers in the characteristics of the functions are all even, the equation comprises 4,096 cases ($=16^3$).

This general result seems to be new, but numerous particular cases occur in Rosenhain's paper. All the important parts of his theory are deduced, viz., the quadratic relations between the constant terms in the ten even functions; the nine ratios of all but one of these by that one are expressed in terms of three independent constants k_1, k_2, k_3; and it is proved that the fifteen quotients of all the functions but one by that one can be expressed in terms of two new variables x_1, x_2, the expressions being given. The connexion between x_1, x_2, and x, y is

$$x=\int^{x_1}\frac{A+Bz}{\sqrt{Z}}dz+\int^{x_2}\frac{A+Bz}{\sqrt{Z}}dz,$$

$$y=\int^{x_1}\frac{A'+B'z}{\sqrt{Z}}dz+\int^{x_2}\frac{A'+B'z}{\sqrt{Z}}dz,$$

where $$Z=z(1-z)(1-k_1^2z)(1-k_2^2z)(1-k_3^2z),$$

and A, B, A′, B′ are perfectly determinate constants.

The quadruple periodicity is investigated at the beginning of the section; and afterwards definite-integral expressions for the periods are obtained, as, for example,

$$K=\int_0^1\frac{A+Bx}{\sqrt{X}}dx;$$

and it is proved that K satisfies a linear differential equation of the fourth order in each of the quantities k_1, k_2, k_3.

It may be mentioned that in dealing with the particular functions a current-number notation ϑ_0, ϑ_1, ... , ϑ_{15} is used in preference to the cumbrous $\Phi\begin{pmatrix}0, 0\\0, 0\end{pmatrix}$, . . .

Section II gives the expansions of all the functions

(i) in trigonometrical series,
(ii) in ascending powers of x and y.

Much use is throughout made of a theorem

$$\Phi\left\{\begin{pmatrix}\lambda, \rho\\ \mu, \nu\end{pmatrix}x, y\right\}=e^{-\frac{2KA\log r}{\pi^2}\frac{d^2}{dx\,dy}}\theta_{\mu,\lambda}(x)\,\theta_{\nu,\rho}(y),$$

($\theta_{\mu,\lambda}(x)$, $\theta_{\nu,\rho}(y)$ being single theta-functions) proved by means of the known values of the single theta-functions. From this many properties are deduced:—

(α.) The expressions for the four pairs of conjugate periods, two actual and two quasi;

(β.) The product theorem of Section I is obtained by means of the product theorem proved for single theta-functions by Professor Smith in the paper previously mentioned;

(γ.) By means of the differential equation which θ is known to satisfy (*see* "Cayley's Elliptic Functions," § 310), it is proved that the general function Φ satisfies two equations in x, y of the form

$$\frac{d^2\Phi}{dx^2}-2x\left(k'^2-\frac{\mathrm{E}}{\mathrm{K}}\right)\frac{d\Phi}{dx}+2kk'^2\frac{d\Phi}{dk}=0,$$

k, k', E having the usual connexion with $\theta_{\mu,\,\lambda}(x)$. These equations are also investigated from the definition as well as

$$r\frac{d\Phi}{dr}+\frac{2\mathrm{K}\Lambda}{\pi^2}\frac{d^2\Phi}{dx\,dy}=0,$$

which it is obvious from the theorem of this section that Φ satisfies.

(δ.) Expressions for all the constants occurring in the expansions of all the functions in powers of x, y are obtained. If we write

$$\vartheta_0=c_0-\frac{1}{2\,!}(\mathrm{B}_{0,0},\ \mathrm{B}_{0,1},\ \mathrm{B}_{0,2})(x,\ y)^2+\ \ldots$$

$$+\frac{(-1)^n}{2n\,!}(\mathrm{N}_{0,0},\ \mathrm{N}_{0,1},\ \ldots,\ \mathrm{N}_{0,s},\ \ldots,\ \mathrm{N}_{0.2n})(x,\ y)^{2n}+\ \ldots,$$

it is proved that

$$c_0=\Delta_1\,.\,\mathrm{K}^{\frac{1}{2}}\Lambda^{\frac{1}{2}},$$

$$\mathrm{N}_{0,2s}=\left(\frac{\pi}{\mathrm{K}}\right)^{2(n-s)}\left(\frac{\pi}{\Lambda}\right)^{2s}\frac{d^n}{dp'^{n-s}dq'^s}c_0,$$

$$\mathrm{N}_{0,2s+1}=\frac{r'\mathrm{K}\Lambda}{\pi^2}\left(\frac{\pi}{\mathrm{K}}\right)^{2(n-s)}\left(\frac{\pi}{\Lambda}\right)^{2(s+1)}\frac{d^{n+1}}{dp'^{n-s}dq'^{s+1}}\Delta_2\,.\,\mathrm{K}^{\frac{1}{2}}\Lambda^{\frac{1}{2}},$$

where $\qquad p'=\log p, \qquad q'=\log q, \qquad r'=2\log r,$

$$\Delta_1=\frac{2}{\pi}\cosh\left\{r'\left(\frac{d^2}{dp'dq'}\right)^{\frac{1}{2}}\right\},$$

with a similar expression for Δ_2.

Section III forms the expression of the addition-theorem. Although no addition-theorem proper exists for theta-functions, that is to say, although $\Phi\ (x+\xi,\ y+\eta)$ cannot be written down in terms of functions of x, y and of ξ, η, an expression is obtainable in every case for

$$\Phi(x+\xi,\ y+\eta)\Phi'(x-\xi,\ y-\eta),$$

Φ, Φ' being either the same or different functions. Since any one function of the sum of two pairs of variables may be combined in a product with any one function of the difference of the same pairs, 256 equations are necessary to give the complete expression of the theorem. These are written down in sixteen sets of sixteen each, that which is common to each set being the function of the difference of the pairs of variables. Denoting by

$$\Theta \ldots \vartheta(x+\xi, y+\eta),$$

$$\Theta' \ldots \vartheta(x-\xi, y-\eta),$$

$$\vartheta \ldots \vartheta(x, y),$$

$$\theta \ldots \vartheta(\xi, \eta),$$

one such equation is

$$c_0^2\Theta_0\Theta_0' = \theta_0^2\vartheta_0^2 + \theta_7^2\vartheta_7^2 + \theta_{10}^2\vartheta_{10}^2 + \theta_{13}^2\vartheta_{13}^2$$

where c_0 is the value of ϑ_0 when x, y are both zero. The obvious analogy with the case of the single theta-functions

$$\Theta^2(0)\Theta(u+v)\Theta(u-v) = \Theta^2(u)\Theta^2(v) - \mathrm{H}^2(u)\mathrm{H}^2(v)$$

(using the ordinary notation) need hardly be pointed out.

In Section IV many of the properties already proved for the double theta-functions are generalised for the "r" tuple theta-functions. Among these are:—

(α.) The periodicity;

(β.) The product theorem, which gives the product of four functions as the sum of 4^r products of four functions; and from it several general equations are deduced;

(γ.) The analogue of the main theorem of Section II, which is for the "r" tuple functions

$$\Phi\begin{Bmatrix}\lambda_1, \lambda_2, \ldots, \lambda_r \\ \nu_1, \nu_2, \ldots, \nu_r\end{Bmatrix} x_1, x_2, \ldots, x_r \Big\} = e^{-\frac{2}{\pi^2}\sum\limits_{s=1}^{s=r}\sum\limits_{s=1}^{t=r} \mathrm{K}_s\mathrm{K}_t \log p_{s,t}\frac{d^2}{dx_s dx_t}} \prod_{t=1}^{t=r} \theta_{\nu_t, \lambda_t}(x_t),$$

and this is used, as before, to obtain

(δ.) The r differential equations of the form

$$\frac{d^2\Phi}{dx_r} - 2x_r\left(k_r'^2 - \frac{\mathrm{E}_r}{\mathrm{K}_r}\right)\frac{d\Phi}{dx_r} + 2k_r k_r'^2\frac{d\Phi}{dk_r} = 0,$$

and the $\frac{1}{2}r(r-1)$ of the form

$$p_{s,t}\frac{d\Phi}{dp_{s,t}} + \frac{2\mathrm{K}_s\mathrm{K}_t}{\pi^2}\frac{d^2\Phi}{dx_s dx_t} = 0,$$

all satisfied by Φ; and to indicate a method of obtaining the constants in the expansions of the Φ's in powers of the x's.

V. "On certain Geometrical Theorems. No. 1." By W. H. L. Russell, F.R.S. Received November 12, 1881.

(1.) The following proof of the equation to a circle inscribed in a triangle, expressed in trilinear co-ordinates, is very short and simple.

Let α, β, γ be the sides of the triangle, A, B, C the opposite angles, and let

$$l^2\alpha^2+m^2\beta^2+n^2\gamma^2-2mn\beta\gamma-2nl\gamma\alpha-2lm\alpha\beta=0$$

be the equation to an inscribed conic. Then when this conic is a circle, the centre is given by the equations $\alpha=\beta=\gamma$, and the equation to the line joining the centre, to the point where γ touches the conic, that is to the point $l\alpha-m\beta=0$, $\gamma=0$, is

$$l\alpha-m\beta+(m-l)\gamma=0.$$

Now, when the conic is a circle, this line must be perpendicular to γ; hence from the condition that two straight lines may be perpendicular to each other (Salmon, "Conic Sections," 6th edition, Art. 61),

$$m-l=l\cos B-m\cos A,$$

or

$$\frac{l}{\cos^2\frac{A}{2}}=\frac{m}{\cos^2\frac{B}{2}}=\frac{n}{\cos^2\frac{C}{2}},$$

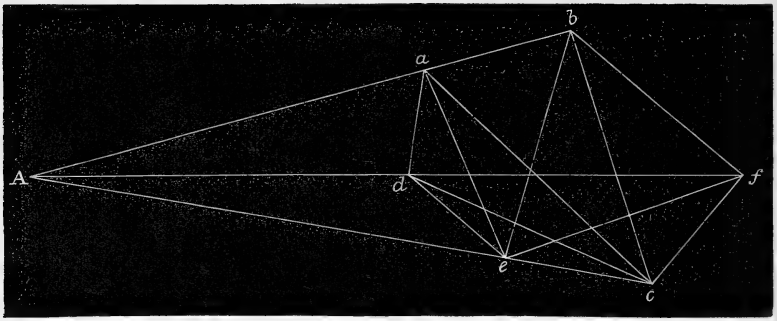
which gives for the required circle

$$\alpha^2\cos^4\frac{A}{2}+\beta^2\cos^4\frac{B}{2}+\gamma^2\cos^4\frac{C}{2}$$
$$-2\beta\gamma\cos^2\frac{B}{2}\cos^2\frac{C}{2}-2\alpha\beta\cos^2\frac{A}{2}\cos^2\frac{B}{2}-2\alpha\gamma\cos^2\frac{A}{2}\cos^2\frac{C}{2}=0.$$

(2.) The following theorem is given by Dr. Salmon in his "Higher Plane Curves":—

If through any point of inflexion A in a curve of the third order there be drawn three right lines meeting the curve in *ab*, *df*, *ec*, then every curve of the third degree passing through the seven points A, *a*, *b*, *d*, *f*, *c*, *e* will have A for a point of inflexion. It follows from this that any curve of the third degree described through the nine points of inflexion of a cubic will have those points as points of inflexion.

Dr. Salmon has given a geometrical proof of this theorem, and this is the only demonstration I have ever seen. I have, therefore, obtained the following analytical proof, which possesses, I think, considerable beauty.



Let A be the origin, Adf the axis of (x), Aec the axis of y. Let $y=lx$ be the equation to Aab, $y=ax+b$ the equation to cd, $y=nx+b$ the equation to ca, $y=cx+e$ the equation to ef, $y=mx+e$ the equation to be, then we may find the equation to ad,

$$y(l-n+a)-lax-lb=0;$$

and similarly the equation to bf,

$$y(l-m+c)-lcx-le=0.$$

In this way it will easily be seen that the six points, a, b, c, d, e, f, are completely determined, and consequently the equation to a curve of the third degree passing through them (see Salmon, "Higher Plane Curves," Art. 162) is

$$ab\,.\,cd\,.\,ef+\theta\,.\,ac\,.\,be\,.\,df+\phi\,.\,ad\,.\,bf\,.\,ce+\psi\,.\,ae\,.\,bd\,.\,cf=0.$$

But since ab, df, ce pass through the origin $\psi=0$, and the equation becomes

$$ab\,.\,cd\,.\,ef+\theta\,.\,ac\,.\,be\,.\,df+\phi\,.\,ad\,.\,bf\,.\,ce=0,$$

and consequently writing down ab, cd, ef, ac, be, df, ad, bf, ce, as given above, we have as the equation of the required cubic—

$$(y-lx)(y-ax-b)(y-cx-c)+\theta y(y-nx-b)(y-mx-e)$$
$$+\phi x(y(l-n+a)-lax-lb)((l-m+c)y-lcx-le)=0;$$

differentiating this equation, and putting $x=y=0$ to determine the value of $\frac{dy}{dx}$ at the origin, we have

$$\frac{dy}{dx}(1+\theta)=l-\phi l^2.$$

Differentiating again, and putting $\frac{d^2y}{dx^2}=0$, $x=y=0$, since the origin is to be a point of inflexion, we shall have—

$$\frac{dy^2}{dx^2}e-(l+a)e\frac{dy}{dx}+(l-\phi l^2)ae+\frac{dy^2}{dx^2}b-(l+c)b\frac{dy}{dx}+(l-\phi l^2)cb$$

$$+\theta e\frac{dy^2}{dx^2}-ne\theta\frac{dy}{dx}+\theta b\frac{dy^2}{dx^2}-mb\theta\frac{dy}{dx}+\phi el(l-n+a)\frac{dy}{dx}+\phi bl(l-m+c)\frac{dy}{dx}$$

or substituting for $l-\phi l^2$, and dividing by $\frac{dy}{dx}$, we have—

$$\frac{dy}{dx}e-(l+a)e+(1+\theta)ae+\frac{dy}{dx}\cdot b-(l+c)b+(1+\theta)cb$$

$$+\theta c\frac{dy}{dx}-ne\theta+\theta b\frac{dy}{dx}-mb\theta+\phi(l-n+a)el+\phi(l-m+c)bl=0.$$

Again substituting $l-\phi l^2$ for $(1+\theta)\frac{dy}{dx}$, and reducing, we obtain the equation

$$(\theta+l\phi)(ae+cb-ne-mb)=0.$$

Hence, if $ae+cb-ne-mb$ vanish, the origin will be a point of inflexion, whatever values we give to θ and ϕ; hence the theorem is true.

(3.) From any point six tangents can be drawn to a curve of the third order; two of these are at right angles to one another, determine the locus of the point.

Substitute for y in the general equation of the cubic $m(x-\xi)+\eta$, arrange the terms of the resulting equation according to powers of (x) and form the discriminant, equate the discriminant to zero, and we shall have an equation of the form—

$$m^6-am^5+bm^4-cm^3+dm^2-em+f=0.$$

Let $$m_1+m_2+m_3+m_4+m_5+m_6=a,$$

$$m_1m_2+(m_1+m_2)(m_3+m_4+m_5+m_6)+m_3m_4+m_3m_5+m_3m_6+m_4m_5$$
$$+m_4m_6+m_5m_6=b,$$

$$m_1m_2(m_3+m_4+m_5+m_6)$$
$$+(m_1+m_2)(m_3m_4+m_3m_5+m_3m_6+m_4m_5+m_4m_6+m_5m_6)$$
$$+m_3m_4m_5+m_3m_4m_6+m_3m_5m_6+m_4m_5m_6=c,$$

$$m_1m_2(m_3m_4+m_3m_5+m_3m_6+m_4m_5+m_4m_6+m_5m_6)$$
$$+(m_1+m_2)(m_3m_4m_5+m_3m_4m_6+m_3m_5m_6+m_4m_5m_6)+m_3m_4m_5m_6=d.$$

$$m_1m_2(m_3m_4m_5+m_3m_4m_6+m_3m_5m_6+m_4m_5m_6)$$
$$+(m_1+m_2)(m_3m_4m_5m_6)=e,$$

$$m_1m_2m_3m_4m_5m_6=f.$$

Since two of the tangents are at right angles to each other, we shall have $m_1m_2+1=0$, and let $m_1+m_2=\mu$, $\Sigma m_3=p$, $\Sigma m_3m_4=q$, $\Sigma m_3m_4m_5=r$, $m_3m_4m_5m_6=s$. Then substituting, we have the following equations:—

$$\mu+p=a \quad . \quad . \quad . \quad (1), \qquad -q+\mu r+s=d \quad . \quad . \quad . \quad (4),$$

$$-1+\mu p+q=b \quad . \quad . \quad . \quad (2), \qquad -r+\mu s=e \quad . \quad . \quad . \quad (5),$$

$$-p+\mu q+r=c \quad . \quad . \quad . \quad (3), \qquad -s=f \quad . \quad . \quad . \quad (6).$$

From these equations we obtain at once—

$$\mu=a-p. \qquad r=f(p-a)-e, \qquad q=1+b-\mu p=1+b-ap+p^2.$$

Hence we have, substituting in (4)—

$$(f+1)p^2-(a+2af+e)p+(1+b)+fa^2+ae+f+d=0 \quad . \quad . \quad (7).$$

Also substituting in (3)—

$$p^3-2ap^2+(a^2+b-f+2)p-a(b-f+1)+e+c=0 \quad . \quad . \quad (8).$$

From (7) and (8) we easily obtain two equations of the form—

$$Ap^2+Bp+C=0,$$
$$A'p^2+B'p+C'=0,$$

then the eliminant is at once seen to be—

$$(A'C-C'A)^2+(BA'-AB')(BC'-CB')=0,$$

the equation to the required locus.

I have not thought it necessary to write down the values of a, b, c, &c., as they are obtained by rules perfectly well known.

Note by W. Spottiswoode, P.R.S.

The second theorem in the foregoing paper follows also as an immediate consequence of a formula given by Cayley in his "Seventh Memoir on Quantics" ("Phil. Trans.," 1861, p. 286). If U represent the cubic and HU its Hessian, then, as is well known, HU passes through the points of inflexion of U. Also, the function $\alpha U+6\beta HU$ will represent an arbitrary curve of the third degree passing through the same points; and, on the same principle as before, its Hessian will pass through its points of inflexion. Now the formula in question is—

$$H(\alpha U+6\beta HU)= \quad \delta_\beta(1, 0, -24S, \ldots)(\alpha, \beta)^4 . U$$
$$-6\delta_\alpha(1, 0, -24S, \ldots)(\alpha, \beta)^4 . HU.$$

But this equation is satisfied by $U=0$, $HU=0$; consequently the equations

$$\alpha U+6\beta HU=0, \qquad H(\alpha U+6\beta HU)=0,$$

are both satisfied by the relations

$$U=0, \qquad HU=0.$$

Hence the theorem given in the text.

VI. "On a Class of Invariants." By JOHN C. MALET, M.A., Professor of Mathematics, Queen's College, Cork. Communicated by Professor CAYLEY, LL.D., F.R.S. Received December 14, 1881.

(Abstract.)

This paper is concerned with two kinds of functions of the coefficients of Linear Differential Equations, which have certain invariant properties.

In the first part of the paper it is shown that every Linear Differential Equation possesses a certain number of functions of the coefficients which are unaltered by changing the dependent variable y to yu where u is any given function of x, the independent variable. These functions bear remarkable analogies to functions of the differences of the roots of ordinary algebraic equations, and many problems, provided they involve only the ratios of the solutions of the differential equation, may be solved in terms of them; for example, the condition that two solutions y_1 and y_2 of a linear differential equation of the third order should be connected by the relation $y_1=y_2x$ is expressed in terms of two such functions of the coefficients of the equation. This problem is analogous to that of finding the discriminant of an algebraic binary cubic.

The second part of the paper is concerning functions of the coefficients of Linear Differential Equations which are unaltered by change of the independent variable, and the theory of these functions is applied to the solutions of problems involving only relations among the solutions of the equation without the independent variable.

In this part of the paper it is shown how to form the condition that the three solutions y_1, y_2, y_3 of a linear differential equation of the third order should be connected by the relation $y_1y_2=y_3^2$, which relation, involving only ratios of the solutions, and not containing the independent variable, can be expressed in terms of either class of the functions of the coefficients considered in the paper; these two methods of writing the condition are accordingly given.

VII. "On the Constituent of the Atmosphere which absorbs Radiant Heat." By S. A. HILL, B.Sc., Meteorological Reporter for the North-Western Provinces and Oudh, India." Communicated by Lieut.-General R. STRACHEY, R.E., F.R.S. Received December 14, 1881.

Notwithstanding the ingenuity with which Dr. Tyndall has made use of the most recent physical appliances to support and confirm the results of his classical researches concerning the behaviour of gases and vapours with regard to radiant heat, his conclusions, in so far as they relate to the comparative diathermancy of dry air and water vapour, have not yet met with general acceptance among meteorologists. There is even, on the part of some, an evident reluctance to accept the decision of laboratory experiments on the question of atmospheric absorption as final, however ingenious, varied, and consistent with one another the experiments may be.

I have, therefore, attempted to approach the question from another side, and to determine, if possible, what constituent of the atmosphere has the greatest absorptive power, by means of the actinometric observations so carefully made at Mussooree and Dehra by Messrs. J. B. N. Hennessey, F.R.S., and W. H. Cole, M.A., in conjunction with the records of meteorological observations made at the same or neighbouring places in the same months of the year. The actinometric observations were made between the 27th October and 4th November, 1869, and between the 31st October and 19th November, 1879. Abstracts of the results have been published by Mr. Hennessey in the "Proceedings," vol. xix, p. 229, and vol. xxxi, p. 154. In both years the observations were made with two actinometers of the Rev. G. C. Hodgkinson's form, marked A and B, each of which appears to have remained absolutely unaltered during the ten years. The results taken from Mr. Hennessey's tables are those expressed in units equal to a tenth of a millimetre of the scale of the instrument A, *glass off*.

The observations which serve to throw most light on the question under discussion are those of the long diurnal series, from 8 A.M. to 4 P.M., made on the 4th November, 1869, and the 12th and 14th November, 1879. In Tables I, II, III, the observed values of the radiation received in three minutes at each hour* are compared with certain symmetrical values computed in the following way.

It has been assumed that Jamin and Masson's law of absorption holds good for each day at both stations; that is to say, that the logarithm of the heat received varies inversely as the thickness of the atmosphere traversed, or, in other words, that the quantity of heat

* On the 4th November, 1869, the mean time of each set of observations was several minutes after the exact hour. The values given in Table I have been interpolated from Mr. Hennessey's figures by means of parabolic formulæ extending over three hours at a time.

absorbed by each unit thickness of the absorbent substance (supposed homogeneous) is proportional to the total heat which falls upon it. This rule was long ago found by Pouillet to be approximately true of atmospheric absorption. The thickness of atmosphere to be traversed by the solar rays at various angles of incidence has been taken to be simply proportional to the secant of the sun's zenith distance. If the vertical thickness of the absorbent atmosphere be taken at $\frac{1}{400}$th of the earth's radius, the error of the preceding assumption is almost insensible for the inclinations in the tables; and below an elevation equal to $\frac{1}{400}$th of the radius lie 68 per cent. of the dry air, and $99\frac{1}{2}$ per cent. of the water vapour of our atmosphere. If, then, R stands for the total radiation that would fall upon the actinometer at the limit of the atmosphere, and r for the observed radiation at the place of observation, when the sun's zenith distance is z, we may put $\log r = \log R - K \sec z$, where K is a coefficient the antilogarithm of which represents the fraction of the total radiation that would be absorbed by a vertical column of the air above the place at the time of the observation. Assuming the K to be constant for each day at each station, I have computed the values of log R independently from the sets of observations made at the two stations; and then, taking the most probable value of R for each day to be that derived from the mean of the two log R's, in which the logarithm deduced from the observations at the upper station* is given double weight, I have recomputed the coefficients marked K_M and K_D respectively, and finally worked out the symmetrical values of r for the hours before and after apparent noon.

Table I.—4th November, 1869.

Hour. Appt. time.	Mussooree.				Dehra.			
	Sec z.	r obs.	r comp.	Diff.	Sec z.	r obs.	r comp.	Diff.
8 A.M.	3·57	842	817	−25	3·54	715	645	−70
9 „	2·21	934	929	− 5	2·20	807	801	− 6
10 „	1·71	990	973	−17	1·70	870	868	− 2
11 „	1·50	1000	993	− 7	1·49	905	898	− 7
Noon	1·43	988	999	+11	1·43	914	907	− 7
1 P.M.	1·50	984	993	+ 9	1·49	900	898	− 2
2 „	1·71	967	973	+ 6	1·70	852	868	+16
3 „	2·21	920	929	+ 9	2·20	786	801	+15
4 „	3·57	799	817	+18	3·54	584	645	+61

Mean R = 1143 log R = 3·05804
K_M = ·04078 for decimal logs
= ·09390 „ natural „
K_D = ·07027 „ decimal „
= ·16157 „ natural „
$\frac{K_M}{K_D}$ = ·5803

* Dehra is 2,229 feet above the sea, and Mussooree 6,937 feet.

Table II.—12th November, 1879.

Hour. Appt. time.	Mussooree.				Dehra.			
	Sec *z*.	*r* obs.	*r* comp.	Diff.	Sec *z*.	*r* obs.	*r* comp.	Diff.
8 A.M.	3·90	744	736	− 8	3·89	622	610	−12
9 ,, ...	2·36	873	852	−21	2·34	764	762	− 2
10 ,, ...	1·80	907	898	− 9	1·79	817	824	+ 7
11 ,, ...	1·56	925	918	− 7	1·55	851	853	+ 2
Noon	1·50	934	924	−10	1·49	850	860	+10
1 P.M.	1·56	915	918	+ 3	1·55	840	853	+13
2 ,, ...	1·80	876	898	+22	1·79	847	824	−23
3 ,, ...	2·36	832	852	+20	2·34	771	762	− 9
4 ,, ...	3·90	727	736	+ 9	3·89	596	610	+14

Mean R = 1064 log R = 3·0271

K_M = ·04106 for decimal logs

= ·09454 ,, natural ,,

K_D = ·06209 ,, decimal ,,

= ·14297 ,, natural ,,

$\frac{K_M}{K_D}$ = ·661

Table III.—14th November, 1879.

Hour. Appt. time.	Mussooree.				Dehra.			
	Sec *z*.	*r* obs.	*r* comp.	Diff.	Sec *z*.	*r* obs.	*r* comp.	Diff.
8 A.M.	3·99	785	762	−23	3·97	639	617	−22
9 ,, ...	2·38	888	892	+ 4	2·37	766	786	+20
10 ,, ...	1·82	941	941	0	1·81	848	855	+ 7
11 ,, ...	1·58	966	963	− 3	1·58	883	884	+ 1
Noon	1·51	978	970	− 8	1·51	892	894	+ 2
1 P.M.	1·58	947	963	+16	1·58	899	884	−15
2 ,, ...	1·82	938	941	+ 3	1·81	849	855	+ 6
3 ,, ...	2·38	873	892	+19	2·37	780	786	+ 6
4 ,, ...	3·99	762	762	0	3·97	620	617	− 3

Mean R = 1123 nearly log R = 3·050483

K_M = ·04231 for decimal logs

= ·09742 ,, natural ,,

K_D = ·06546 ,, decimal ,,

= ·15063 ,, natural ,,

$\frac{K_M}{K_D}$ = ·644

These tables suggest two independent methods of inquiring which among the atmospheric gases has the greatest power of arresting radiant heat. We can inquire which constituent of the atmosphere is subject to a diurnal variation most resembling that of the absorption coefficient, and also which constituent is distributed vertically in a manner most closely approaching to that of the absorptive substance.

If the coefficient K were truly constant for each day, as has been assumed, the positive and negative differences between the observed and computed values of *r* should be irregularly distributed; but we find that, almost without exception, the computed values are too low in the forenoon and too high in the afternoon at Mussooree, while at Dehra there is no such regular order in the differences. The excess of the morning over the afternoon radiation at Mussooree and their approximate equality at Dehra are very clearly seen in the averages of the three sets of observations, which are the following:—

Hour.......	8	9	10	11	12	13	14	15	16
Mussooree ..	790	898	946	964	967	949	927	875	763
Dehra	659	779	845	880	885	880	849	779	600

The departure from complete symmetry at Dehra is due chiefly to one observation at 4 P.M. on the 4th November, 1869, when probably there was a slight haze partially obscuring the sun.

The absorption of heat by the atmosphere on a clear, calm day cannot be, in any appreciable degree, a mere apparent effect due to the scattering of the rays brought about by disturbances set up in the atmosphere through heating from below; for any variations in the amount of such scattering must be even more apparent at the lower station that at the upper one, because, to get to the lower station, the rays must pass through more of the disturbed atmosphere. Moreover, such disturbances, and the apparent absorption caused by them, would probably be at least as great during the hours of rising temperature (up to about 1 P.M.) as when the temperature is falling. The increased absorption of the afternoons at Mussooree must therefore be due to the fact that more of the absorbent substance—whatever it be—lies above the level of the station in the afternoons than in the mornings, while above the lower station the total quantity of this substance is practically constant throughout the day; that is to say, the absorbent substance is carried upwards during the day and probably sinks downwards again at night.

Such an upward movement of the total atmosphere occurs under the influence of diurnal heating, but what proportion of the air that is lifted above Mussooree by expansion from below remains there cannot be exactly determined. The barometer falls from 10 A.M. to

4 P.M. at all elevations where observations have been made in the Himalaya, as it does on the plains. In any case, the fraction of the total atmosphere which accumulates above Mussooree during the day hours must be a very small one, and its influence in increasing the absorptive power of the upper atmosphere may be safely neglected.

With water vapour the case is different. This diminishes so rapidly as we ascend* that, if it be the chief absorbent substance, a small variation in the quantity of it lying above the higher station will considerably affect the absorbing power there observed. In the following table the value of K_M for each hour of observation, computed from the mean of the three series, is compared with the mean hourly values of the barometric pressure and vapour tension for November at Simla, a neighbouring station of nearly the same altitude, and with the vapour tension and cloud proportion observed at Roorkee, a station 40 miles S.S W. from Mussooree and 887 feet above the sea. General Boileau's observations at Simla in 1843–5, from which the figures for that station have been taken, were made inside a house, and do not strictly represent the variations in the humidity of the external air. The normal variation of humidity in the upper air may, however, be inferred with some approximation to the truth from the variations of cloud; for though the days of observation were without cloud, like most days in November in North India, there is no reason to suppose that the diurnal movements of the vapour were different in direction on those days from what they are when the humidity is so high that clouds are formed.

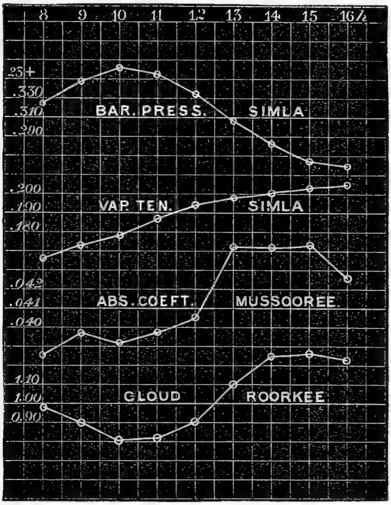
Table IV.

Hour.	Absorption coefficient. Mussooree.	Barometric pressure. Simla.	Vapour tension. Simla.	Cloud proportion. Roorkee.	Vapour tension. Roorkee.
8 A.M.	·03862	23·323″	·166″	0·99	·346″
9 „	·03966	23·349	·172	0·90	·367
10 „	·03908	23·360	·179	0·80	·373
11 „	·03969	23·353	·186	0·81	·372
Noon	·04051	23·333	·194	0·90	·362
1 P.M.	·04409	23·307	·198	1·10	·344
2 „	·04405	23·283	·200	1·25	·332
3 „	·04416	23·267	·202	1·26	·332
4 „	·04264	23·259	·204	1·23	·354

It will be seen from Table IV, and from the diagram below, that the variation of the absorption coefficient is similar in its chief feature—the increase from morning to afternoon—to that of the

* See Strachey, "Proc. Roy. Soc." (vol. 11, p. 182).

vapour pressure observed at Simla, but totally different from the variation of the barometric pressure; while the absorption curve agrees closely with that of the humidity of the upper atmosphere as indicated by cloud, even in minor points like the decrease at 10 A.M.



Also, since the hourly observations at Roorkee show that the pressure of vapour there is less in the afternoon than in the morning, it is probable that the variations, both above and below, are caused by an upward movement of the vapour during the day. Such a movement would not affect the absorption of heat by the whole depth of the atmosphere, if water vapour be the chief absorbent substance, and we find that at Dehra the absorption in the afternoon is little, if at all, greater than in the morning. The evidence of the diurnal variation, therefore, points strongly to the conclusion that water vapour is the chief absorbent.

The question may be answered more directly by the second method, the determination of the law of vertical distribution of the absorbing matter. Since both stations lie above the dust-haze so common over India in the cold weather, and since the days of observation were free from cloud, we may assume that the absorbent substance we have to deal with is a gas distributed according to the barometric formula; and therefore the observations at two places suffice to determine the law approximately. We have, then, for each day, log $K_M =$ og $K_D - \frac{\Delta h}{C}$, where Δh is 4,708 feet and C is a constant for the da y Computing C in this way for each day, and also C_1 and C_2 for the dry air and water vapour respectively, taking $\frac{1}{C_1}=\frac{\log B_D-\log B_M}{\Delta h}$; $\frac{1}{C_2}=\frac{\log f_D-\log f_M}{\Delta h}$ where f is the vapour tension, and B the height of the barometer corrected for vapour tension, we get the following values :—

Date.	C	C_1	C_2
4th November, 1869	19,922	64,409	17,210*
12th " 1879	26,213	66,370	26,814
14th " "	24,840	66,066	25,499
Mean	23,658	65,615	23,174

In computing C_2 the vapour tensions observed at the Meteorological Observatory of Roorkee have been combined with those of Dehra, because the latter seem to be somewhat too great at all times of the year in comparison with those for other places in the Himalaya at nearly the same altitude,† while Roorkee is generally a little too dry. In any case, with such a variable element as water vapour, it is best to deduce the law of distribution from as many observations as possible.

The difference between the values of C and C_2 is so small, considering the nature of the observations, while that between C and C_1 is so very great, that there can be very little error in agreeing with Dr. Tyndall that the absorptive power of dry air is sensibly nothing, and that the total absorptive power of the atmosphere is due to the water vapour it contains.

The true absorption coefficient at sea-level, on the supposition that the absorbent substance increases in density according to the same law as between Mussooree and Dehra, appears to have been a good deal less on the two days of observation in 1879 than the mean value found by Pouillet in 1838, while its value on the 4th November, 1869, differed but little from Pouillet's mean result. Pouillet found the absorption of a vertical column of transparent atmosphere at Paris to vary between ·18 and ·27 of the total incident radiation, the mean being about ·24. From Mr. Hennessey's observations the coefficient for Naperian logarithms at sea-level appears to have been

* Computed from the observations made at the Meteorological Observatories of Dehra and Roorkee, and at Chakrata, 30 miles north of Mussooree and 7,160 feet above the sea. No observations of humidity were made at Mussooree on this day.

† This has been pointed out by the writer in a paper on the meteorology of the North West Himalaya, published in the "Indian Meteorological Memoirs," vol. i.

·209 on the 4th November, 1869, and ·174 and ·185 respectively on the 12th and 14th November, 1879.

If the differences in these values of the total absorption be caused entirely by variations in the quantity of aqueous vapour in the air, the fraction of the total incident heat which is arrested before reaching the ground will be a direct function of the vapour tension at the place of observation, and an inverse function of the rate of diminution of the vapour tension with height. We may suppose it to be simply proportional to the total quantity of water vapour over the place of observation. This has been shown by Dr. J. Hann* to be equal to a depth of water, $f\times\frac{\cdot0010582}{1+\alpha t}\times\cdot4343$ C, where f is the vapour pressure expressed in units of height of mercury, and C is the constant of the vapour formula in metres. Neglecting the temperature coefficient, which should probably enter into C also, and reducing to English measure, the quantity of rain that would be formed by the complete condensation of the vapour over any place is given by the formula, $Q=f\times\cdot00014$ C inches, where f is expressed in inches of mercury, Q in inches of water, and C in feet. At Mussooree, on the days of observation in 1879, the several quantities had the following values :—

Date.	K	f	C_2	Q
12th November	·04106	·221″	26,814 ft.	·829″
14th "	·04231	·183	25,499	·653

If now $K=\alpha Q$, the value of α on the 12th November is found to be ·0495, and on the 14th, ·0648. The fraction of the total radiation absorbed from day to day therefore does not bear a constant relation to the quantity of aqueous vapour in the air; and, consequently, it seems probable that the *quality* of the sun's heat is subject to considerable variations from day to day. If this be so, it will be impossible to arrive at comparable actinometric results from a few observations about apparent noon each day, unless the observing station be sufficiently elevated to lie above the greater part of vapour atmosphere.

Unfortunately no hygrometric observations were taken at Mussooree in November, 1869, so that it is impossible to determine precisely, from the actinometric observations made there by Mr. Hennessey, whether the radiation emitted from the sun was more or less susceptible of absorption in 1869 than in 1879. At Dehra, however, the

* "Zeitschrift für Meteorologie," Band IX, page 199.

psychrometer was observed every day at 9.30 A.M. and 3.30 P.M., and from these observations, in conjunction with the figures already given, we can find an approximate value of a for the 4th November, 1869, as well as for the two days in 1879. In the following table the quantities from which a is computed and its value for each day are shown:—

Date.	K	f	C_2	Q	a
4th November, 1869 ..	·07027	·344″	17,210 ft.	·829″	·0848
12th " 1879 ..	·06209	·375	26,814	1·407	·0441
14th " " ..	·06546	·302	25,499	1·078	·0607

The vapour tension observed at Dehra is a strictly local phenomenon, as has been above pointed out, but still the values of a for the two days in 1879 accord so well with those deduced from the observations at Mussooree, that there can be little doubt that water vapour had a greater absorbent effect on the radiation of the 4th November, 1869, than on that emitted from the sun on the other days.

From the observations made simultaneously at Mussooree and Dehra, for several days near apparent noon, we may perhaps determine approximately whether the mean emissive power of the sun was greater at the beginning of November, 1869, or in November, 1879. There are only three quantities to determine for each year, the total radiation at the limit of the atmosphere, the absorption coefficient for Mussooree and the same for Dehra, and we have three relations between these quantities:—

$$(1)\ \text{Log}\ R = \log r_M + K_M \sec z_M,$$

$$(2)\ \text{Log}\ R = \log r_D + K_D \sec z_D,$$

$$(3)\ \text{Log}\ K_M = \log K_D - \frac{4{,}708 \text{ feet}}{C}.$$

In (3) we may take C to be the constant of the formula for water vapour, which, for 1869, may be computed from the observations at Roorkee, Dehra, and Chakráta. From Mr. Hennessey's tables and the Meteorological Observatory records, I find the following mean values for the required data:—

Year.	r_M	r_D	Sec z_M	Sec z_D	C.
1869	980	902	1·401	1·398	19,077
1879	954	887	1·475	1·471	25,030

These data yield the following results :—

Year.	R.	K_M	K_D	True K at sea-level.
1869	1095	·03454	·06094	·1836
1879	1093	·03995	·06160	·1741

As far as we can judge from seven days' observations in 1869 and sixteen days in 1879, it would seem that the mean radiation of the sun, and the mean absorption of the atmosphere lying above Dehra were practically the same in the two years; while the absorption at Mussooree was slightly greater, and that at sea-level somewhat less in 1879 than in 1869.

On the mean of all the days the quantity of water vapour in the air above Dehra was equal to ·846 inch of rain in 1869, and 1·174 inch in 1879; and the corresponding values of α, the coefficient of absorption for common logarithms, when the water vapour is equal to an inch of rain, were ·072 and ·0525 respectively. The vapour tensions at Dehra are of too local a character to admit of any safe inference from these figures; but, as far as the evidence goes, it points to the conclusion that the radiation emitted by the sun during the days of observation in 1869 was more readily absorbed by water vapour than that emitted in 1879.

It is to be hoped that the observations which are to be commenced next year at Leh—a station 11,500 feet above the sea—that is, lying above four-fifths of the absorbent atmosphere—will enable us to solve the all-important problem whether the sun's heat varies to any appreciable extent or not; but simultaneous observations at a lower station, such as Mussooree, will be required to settle without doubt the further question, whether there is any sensible variation in the quality of the solar rays, as tested by actinometric methods, that can be compared with the changes in the absorption lines which are observed in the spectra of spots.

Since writing the above, I have seen a report of a lecture* by M. Violle, Professor at the Faculté des Sciences, Grenoble, in which the lecturer described some simultaneous observations made by himself and another at the summit of Mont Blanc and Grenoble, and at the Grands Mulets and Glacier des Bossons, on the 16th and 17th of August, 1875. M. Violle's values for the heat received in a minute by a square centimetre of surface exposed perpendicularly to the sun's rays are given in calories in the following table :—

* "Revue Scientifique," April 6, 1878.

Date.	Place.	Altitude. (feet).	Heat received per minute.
August, 1875	Limit of atmosphere	?	2·54
" 16th	Mont Blanc	15,780	2·39
" 17th	Grands Mulets	10,010	2·26
" 17th	Glacier des Bossons......	3,940	2·02
" 16th	Grenoble	700	1·81

From these results M. Violle concluded that the absorptive effect due to water vapour was about five times as great as that due to dry air; but when the constant C, of the logarithmic formula for the vertical distribution of the absorbent substance is computed, it is found to be 22,137 feet on the 16th August and 22,580 on the 17th. These numbers agree so closely with the mean of those found above, and with the constant of the average vapour formula found by Dr. Hann,† viz., 6,517 metres or 21,382 feet, that it is evident that in the Alps, as in the Himalayas, practically the whole absorptive power of the atmosphere is exercised by the water vapour it contains.

The Society adjourned over the Christmas Recess to Thursday, January 12th, 1882.

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A Photograph of Colonel Tennant, R.E., F.R.S.

"On *Trichophyton tonsurans* (the Fungus of Ringworm)." By George Thin, M.D. Communicated by Professor Huxley, Sec. R.S. Received February 19, 1881. Read March 3.

[Plate 2.]

The disease of the scalp popularly known in England as ringworm is described in medical works under the names herpes tonsurans and tinea tonsurans. When it occurs on the skin of the body it is known as tinea circinata and also as herpes tonsurans. The disease is widely spread in the human subject, exists in all climates, and also occurs in the horse, ox, and dog. It can be communicated from these animals to each other and to man.

It was shown almost simultaneously by Gruby,* in France, and by Malmsten,† in Sweden, that the disease is due to the growth in the hairs and in the horny layers of the epidermis of a fungus which was named by Malmsten *Trichophyton tonsurans.* The statements of Malmsten and Küchenmeister‡ that the parasite is found only amongst the cells which have undergone the horny change, that is to say, in the hair-shaft, between the hair-shaft and the internal root-sheath, and in the horny layer of the epidermis, have been recently confirmed by the evidence of sections made through the affected skin in the horse§ and in man. The parasite is not found amongst the living cells of the epidermis.

* "Comptes Rendus," &c., 1844, vol. xviii, p. 583. (*Vide* "Végétaux Parasites." Par Ch. Robin. Page 417.)

† "Müller's Archiv," 1848. (Swedish original, *Trichophyton tonsurans,* Harskärande Mogel. Stockholm. 1845.)

‡ Sydenham Society's translation. "On Animal and Vegetable Parasites of the Human Body," vol. ii, p. 141.

§ *Vide* a paper by the author, "On the Condition of the Skin in tinea tonsurans," in the 61st volume, and another by Dr. Frederick Taylor in the 62nd volume, of the "Transactions of the Royal Medical and Chirurgical Society."

The fungus, as at present known, consists of a mycelium and spores, and very little has been determined regarding its nature. Attempts that have been made to cultivate it artificially have led to contradictory conclusions. Lowe, in 1850,* was induced to believe that *Trichophyton tonsurans* is a spore formation of the fungus of favus—a specifically distinct parasitic disease of the skin—and that both are forms of Aspergillus. Neumann,† on the other hand, whilst believing that his cultivation experiments showed that herpes tonsurans and favus are produced by the same fungus, traced it in both diseases to *Penicillium glaucum*. Dr. Atkinson,‡ again, was led by his cultivations to believe that the fungus belongs to the Mucors, and is probably *Mucor mucedo*.

The reason why the botanical relations of the parasite to the common fungi have been so difficult to determine has been stated by De Bary. "If," he remarks,§ speaking of the vegetable parasites of the skin, "the parasites, when removed from the bodies of their hosts, are cultivated in water, sugar solution, &c., the vegetation of their spores is then observed, and after a short time there appears in the fluids the universally wide-spread fungi, *e.g.*, *Penicillium glaucum*, *Aspergillus glaucus*, or *Torula*. The latter and the mycelium of Penicillium resemble more or less the spores and mycelium of the parasites in question, and, being found in immediate contact with them, it seems as if they had been developed from them in the artificial medium."

Köbner,|| who endeavoured to solve some of the problems connected with the development of the parasite by clinical experiments, found that *Trichophyton tonsurans*, when inoculated on the skin, produced only herpes tonsurans, and that he could not produce this disease by inoculation with *Penicillium glaucum*.

A strong reason exists, independently of experimental results, for believing that trichophyton is not a form of the common fungi. The facility with which ringworm is communicated from one child to another by contact, or by interchange of caps, shows that the fungus takes root easily on the scalp, whilst, as many a country medical practitioner can testify, bareheaded children may be exposed indefinitely to contact with all the spores with which the atmosphere is pregnant without a single instance of the disease being produced.

In endeavouring to cultivate *Trichophyton tonsurans* artificially, it was clear to me that one of the chief difficulties to be overcome was to

* "Botanical Transactions." Edinburgh. 1850.

† "Lehrbuch der Hautkrankheiten." 2nd edition.

‡ "On the Botanical Relations of the *Trichophyton tonsurans*." "New York Medical Journal," December, 1878.

§ Hofmeister's "Handbuch der Physiologischen Botanik," Band 2, Abth. 1, p. 224.

|| "Klinische und Experimentelle Mittheilungen." Erlangen. 1864.

avoid confusing accidental growths of common fungi with the spores and mycelium of the parasite. The size of the spores and mycelium is not to be relied on for this purpose, but their arrangement in an affected hair offers facilities for ascertaining whether in any given case trichophyton has developed.

When a hair is extensively affected with ringworm fungus, the root for a considerable extent is loaded with spores in all its thickness, and along its free borders the spores on the extreme edge can be seen under the microscope with perfect distinctness. It was thus evident to me that if there were observed at an early stage of the cultivation a growth of those spores in the sides of the hairs which from their position could be recognised as ringworm spores, the fallacy of deception by admixture of adventitious fungi would so far be avoided.

At an early stage of my investigations, Mr. Banham, of the Brown Institution, showed me a preparation in which ringworm spores had in considerable numbers pushed out a tubular projection, by which their length had become at least double their breadth, and which was evidently the beginning of growth. This growth had taken place in a prepared cell in a drop of aqueous humour, but Mr. Banham informed me that he had not succeeded in getting the cultivation to go farther.

The first attempts I made at cultivation were with ringworm hairs, which had been kept in my house for varying periods, having been put aside for the purpose of the investigation; but, after a series of negative results, I confined myself entirely to hairs freshly extracted from the heads of children affected with ringworm. These were usually put in the different solutions with which I experimented within periods varying from a quarter of an hour to two hours. When these ringworm hairs are placed in contact with fluids at a high temperature (92° to 98° F.), the spores soon show an outer surface or capsule, containing a spherical mass within it. This seems to be to a great extent independent of the nature of the fluid, and it is very apt to be mistaken for the first beginning of growth. When growth does not take place the appearance remains stationary. A variety of solutions were tried without result. These were used at first in cells, the hair being laid on the inner surface of the cover-glass of the cell and a drop of the solution placed over it. The hair was sometimes covered with the drop and sometimes only moistened; in the latter case a ring of damp blotting-paper was placed in the bottom of the cell, to prevent evaporation. The cells were then placed in an incubator. The temperature within the incubator varied during the course of the experiments between 92° and 98° F., but was mostly from about 96° to 98°.

As these negative results afford evidence that *Trichophyton tonsurans* and the fungi usually present in the atmosphere are essentially different, they are worthy of being recorded.

Experiments.

1. With the following solution:—

Sodæ Phosph....................	1 grm.
Ammon. Tart....................	10 „
Aquæ distill....................	1,000 cub. centims.,

which I found had been in use in cultivation experiments at the Brown Institution.

Thirteen cells with ringworm hairs in contact with this solution were placed at different times in the incubator, viz., two for three days, three for four days, five for six days, two for nine days, and one for fourteen days. There was no growth of trichophyton in any of them.

Some minute particles of bread, on which common mould had been sprinkled, were placed in a drop of the same fluid in a cell, and placed in the incubator. Long mycelial threads grew on the under surface of the cover-glass.

Again, a piece of bread slightly mouldy at some points was soaked in the same fluid, and with ringworm hairs placed on it, was put into a bottle, and the bottle placed in the incubator. The roots of the hairs were found entwined with a rich mycelial growth of fungi, considerably larger than the fungus of ringworm, but the spores of trichophyton could be seen after preparation and maceration in potash to be undeveloped.

2. A fluid (known, I believe, as Cohn's fluid) with the following composition:—

Magnesium Sulphate..........	1 grm.
Potassium Nitrate	1 grm.
Calcium Phosphate	0·2 grm.
Distilled Water	500 cub. centims.

One per cent. ammonium tartrate to be added before use.

Two cells charged with ringworm hairs and the above fluid were placed at different times in the incubator, one for two and the other for eight days. The fungus grew in neither. Two hairs containing spores were floated on the surface of the fluid in a test-glass, and placed in the incubator for four days. There was no growth. Other ringworm hairs, placed in a small tube, were sunk at the bottom of the same test-glass. There was again no growth.

Ringworm hairs were placed on bread soaked in the fluid, the bread being then put in a bottle and placed in the incubator for four days. The hairs were found enveloped in aspergillus. Trichophyton spores had not grown; being found after maceration to be in the same condition as in a diseased hair freshly extracted from a ringworm patch.

3. *Milk.*—The milk used had been purified by boiling in a water bath, and had been kept pure in purified glasses, according to the method described by Mr. Lister.*

The results of the experiments were negative, but are in other respects interesting.

A hair from a patch of ringworm was placed on the surface of milk, in a glass otherwise kept pure and set aside at the room temperature on the 16th March. It was taken out on the 27th, a fungus growth having been visible to the naked eye for several days. The root of the hair was found enveloped in *Penicillium glaucum.* When the hair had been macerated in a solution of potash it was seen that it had been healthy, and it contained no ringworm spores.

Two hairs, which turned out to be ringworm hairs, were kept on the surface of milk for eighteen days. There was large development of fungus, but I could obtain no evidence that it had any connexion with the ringworm spores. A supposed ringworm hair, after being on the surface of milk for three days in the incubator was found enveloped in fungus, but maceration in potash showed that there was no trichophyton in the hair. A ringworm hair in a tube at the bottom of the milk glass in two days in the incubator had developed nothing.

Two experiments showed that even with milk the development of a fungus does not necessarily follow when protected pure glasses are used.

A supposed ringworm hair was placed on pure milk in a protected glass in the incubator for three days. No fungus of any kind grew, and maceration of the hair in potash showed that the hair was not affected with trichophyton. Another supposed ringworm hair, but which subsequent examination showed to contain no spores, was placed in pure milk in a protected glass for thirteen days without any fungus developing.

My attempts to grow trichophyton in milk thus failed.

In connexion with Mr. Lister's experiments on the lactic fermentation, it may be worthy of remark that the glasses used were all charged with pure milk by the method he has described, and that the milk remained unchanged until they were used for these experiments. With the introduction of the hairs bacteria were necessarily also introduced, but the glasses being immediately protected, no other bacteria than those adhering to the hairs were present. The hairs, after they were extracted from the patients' heads, had been kept in paper until they were brought in contact with the milk. Various although usually very slight changes took place in the appearance of the milk, but in none of the glasses did the common lactic fermenta-

* "On the Lactic Fermentation." "Transactions of the Pathological Society of London," vol. xxix.

tion occur, so far as a curdled condition is evidence of that change. A thin stratum of clear fluid in one case appeared on the surface of the milk, but to a much less extent than in ordinary curdling.

4. *Aqueous Humour.*—Two experiments only were made with aqueous humour, the cells charged with it being placed in the incubator. In one after five days there was no growth of the ringworm spores; in the other, during forty-eight hours, a bulging had taken place from some of the spores, evidently the beginning of growth. On account of the greater convenience in getting large quantities of fluid vitreous humour was used instead of aqueous humour in subsequent experiments.

5. *Tap Water.*—A ringworm hair, moistened with tap water, was placed in the incubator. During nine days there was no growth.

6. *Carrot Infusion.*—One cell was prepared with carrot infusion. During four days no growth took place.

7. *Salt Solution.*—Strength 0·75 per cent.—A cell thus prepared was placed in the incubator for five days: no growth. Hairs were floated on the solution in a glass in the incubator for six days without growth of trichophyton spores.

8. *Turnip Infusion.*—Bread, soaked in turnip infusion, was placed in a box and ringworm hairs placed on the bread at different points. The box was covered and placed on the top of the incubator, where the heat was less than inside. After four days the bread was found covered with fungi.

The ringworm hairs were picked out, macerated in potash, and examined. All the spores were round, and there was no appearance on the sides of the hairs of bulging or early mycelium formation.

Ringworm hairs were floated on pure turnip infusion in protected glasses, and placed in the incubator for five days. They were then examined. The spores observed in the hairs were all round, and there was no growth from the sides. Another experiment of the same kind in which the hairs were examined after four days, showed a like negative result.

In another similar experiment the hairs were found after eight days imbedded in fungus, *Penicillium glaucum.* The hairs, when examined, were seen to be full of spores, which had not sprouted from the sides in the least degree; those which were lying on the extreme edge of the hair being found round and unchanged.

In two cells charged with diseased hairs, minute morsels of bread and turnip infusion, and placed in the incubator, no ringworm growth took place during four days; and another experiment, in which the hairs were floated on the infusion and kept in the incubator for seven days, also showed a negative result.

The attempts to grow trichophyton in turnip infusion thus all failed.

9. *Egg Albumen.*—Seven attempted cultivations with egg albumen in the incubator, and one at room temperature, also one with acid albumen in the incubator, conducted in the same manner as those already described, all failed.

10. *Egg Albumen and Potash.*—Four attempted cultivations with albumen, to which a small proportion of solution of potash had been added, also failed. In two of them the hairs were floated on the surface of the fluid in glasses placed in the incubator; in the other two the hairs had been sunk to the bottom.

11. *Vitreous Humour and Potash.*—Three cultivation experiments with vitreous humour and potash, similarly conducted, in one of which the ringworm hairs were floated on the top, whilst in the other two they were sunk to the bottom, also failed.

12. *Vitreous Humour.*—As vitreous humour is the only fluid with which I have succeeded in cultivating trichophyton, and as, even with this fluid, special conditions are necessary, it is desirable to describe the experiments and mode of procedure in detail.

It will be convenient to divide them into—

1. Cultivation in cells at incubator temperature; no growth taking place.

No. of cells.		No. of days in incubator.	Remarks.
1	......	2	
3	......	4	
4	......	5	
1	......	6	
3	......	7	
6	......	8	
5	......	9	
1	......	10	
1	......	11	
2	......	12	
5	......	..	No. of days in incubator not noted.
32			

The cells were, during these periods, examined daily, and immediately afterwards put back again into the incubator. Those regarding which it is remarked that the time was not noted are the cells which were used in the earlier experiments. They were kept a long time, and frequently examined, the date on which they were finally taken out not being noted.

In the earlier of these experiments, the hairs used had been extracted for some time from the patients, and had been kept folded in paper. This may possibly have had something to do with the negative results.

In a large proportion of them, however, freshly extracted hairs were used.

2. Cultivation in cells at room temperature. No growth took place.

No. of cells.		No. of days.
1	......	2
1	......	10

3. About the time when the experiments referred to in the above tables were ended, it occurred to me that the reason why the spores did not grow was because the hairs were submerged in the fluid.

Acting on this idea, I moistened the under side of the cover-glass of the cell, taking care that the roots of the hairs used were not covered with the fluid. For the first time I obtained evidences of undoubted growth. The convenience of the cell for such experiments was now well shown, as I was able to observe the earliest evidence of mycelial growth from the spores on the sides of the hairs without disturbing the preparation, which could be put back again into the incubator without any part of it being moved. In these instances there was no possibility of a mistake being made by confounding adventitious fungi with trichophyton. The spores of the latter could be examined *in situ* through the cover-glass, and as germination took place the spores could be seen elongating into a mycelium from their original position on the edge of the hair.

In three cells prepared in this way trichophyton grew. The first appearance of elongation in the spores was observed after the preparation had been a few hours in the incubator, the hairs having been transferred from the head of the child to the incubator after a very short interval. During the two following days the growth went on to the formation of mycelium. The mycelium, however, ceased to grow after having attained a very moderate length; spore formation soon beginning to take place.

(Similar cells prepared in the same way with Cohn's fluid and with hairs from the same patch showed no signs of growth.)

The disadvantages associated with this mode of cultivation were found to be the following:—

It was difficult to hit on the right quantity of fluid. If there was too much the spores did not grow, and if there was too little they did not grow, and when the quantity happened to be sufficient to encourage germination it was not enough to maintain growth after the mycelium had attained a comparatively limited length.

This difficulty was got over in the following way:—

4. When the hair was laid gently on the surface of vitreous humour in a test-glass, it did not sink, and by simply floating the hairs I was able to secure the requisite conditions of moisture without immersion.

The vitreous humour used had been prepared in the manner described in a paper on *Bacterium fœtidum* ("Proc. Roy. Soc.," No. 205, 1880), and the hairs were laid on this pure fluid, and placed in the incubator in protected glasses. The only source of contamination was the organisms that were introduced with the hair. Experiment showed that whilst in all cases there was a free development of bacteria, the development of adventitious fungi was frequently avoided.

The following table gives the results of twelve cultivations made by this method :—

Cultivations on the surface of Vitreous Humour in Test-glasses in the Incubator.

No. of experiment.	Growth of trichophyton.	No. of days in incubator.	Remarks.
1	No.	6	Adventitious fungi grew.
2	No.	6	
3	Yes.	3	
4	Yes.	2	
5	Yes.	2	
6	Yes.	4	
7	No.	8	
8	Yes.	8	Slight growth.
9	Yes.	3	
10	Yes.	7	
11	Yes.	3	Slight growth of trichophyton: much adventitious fungi.
12	No.	6	Growth of aspergillus.

One experiment was made to ascertain whether trichophyton could be cultivated at ordinary temperatures.

On the 20th April several ringworm hairs were placed on the surface of vitreous humour in a protected flask, which was put aside and kept at the ordinary temperature of the work-room. On the 3rd May the hairs were examined. Trichophyton was found to be growing from their edges, but the growth was not so luxuriant as it was usually found to be after two days' cultivation when the test-glass was kept in the high temperature of the incubator.

In one recorded experiment the hairs extracted from a ringworm patch did not happen to contain trichophyton. After three days' cultivation in the incubator no fungus of any kind had grown.

Several other similar experiments, which were not accurately noted, showed that if a hair which did not contain trichophyton was not much exposed before being placed on the vitreous humour, the glass containing it might be placed for several days in the incubator without the development of adventitious fungi.

It follows from the facts recorded in this table that although the method may be relied on for the cultivation of ringworm fungus, it cannot be considered certain.

I am not able to account for the failures recorded in experiments 1, 2, 7, and 12, but they did not surprise me. Simultaneously with the experiments on trichophyton I had made a number of cultivations of the common fungi found in our houses, and had learned how delicate are the conditions of growth to which they are all subject. One of the most important of these conditions is the requisite degree of moisture, which must be neither in deficiency nor excess. The failures recorded in these experiments may possibly have been due to the hairs having become too much immersed, or the spores themselves may have been incapable of germination from changes effected in them by inflammatory exudation around the hair follicles before they were extracted.

The growth observed consisted in a development of mycelium from spores, and in the formation of spores within the mycelium, as is portrayed in the drawings in the plate. No organs of fructification were observed.

Two experiments were made with ringworm hairs which had been sunk in water. In one case the length of time of the immersion is not noted; in the other the hairs were immersed six days. In neither case did trichophyton grow when an attempt at cultivation on vitreous humour was made. Considering the uncertainty of vitreous humour cultivations, these two experiments have only a very limited value, but, so far as they go, they support the inferences which follow from other experiments made in the same direction. The hairs in which trichophyton grew were all freshly extracted, but one experiment was made with two hairs, kept dry in a box for thirteen days. The spores were very numerous in these hairs; only one appearance of growing mycelium was observed, a spore having sprouted on the side of the hair. There were, on the other hand, some similar experiments with negative results. Four cultivations were tried with hairs which had been kept eleven days, and three with hairs which had been kept twenty-two days; in all of them the spores remained unchanged.

The value of these experiments is, on account of the uncertainty of the cultivations, not very great, but it may be well to put them on record. The same remark applies to experiments made with hairs taken from patches which were under treatment. The vitality of trichophyton is destroyed as a result of many varieties of treatment, the essential feature in all of which is that they produce inflammation of the skin. As soon, therefore, as I had determined that the spores in untreated hairs could be grown in a fairly large proportion of the experiments made, I undertook cultivations with hairs extracted from patches which were under active treatment for the cure of the disease. With one exception, and in that one the growth was open to doubt, all these cultivations failed. Nineteen such cultivations were attempted, in two the hairs being on the vitreous humour in the incubator for two days, in eight for three days, in six for four days, and in three for five days. The treatment had consisted in rubbing into the scalp, on the affected places, sulphur ointment and mercurial ointments of various kinds and strengths.

The failure to cultivate trichophyton in these cases did not coincide in point of time with the cure of the disease, for in many of them the malady followed its somewhat tedious course for a considerable time after the dates of the experiments.

The fact that I had been unable to produce growth of trichophyton in cells, so long as the spores were completely immersed in vitreous humour, led me to make the following experiments. Ringworm hairs were extracted from a patch of untreated ringworm. Some of them were inserted into a small glass tube, which was placed at the bottom of the test-glass, and others were floated on the surface of the fluid in the usual way. After two days the hairs were examined. There was an abundant growth of mycelium around the roots of those hairs which were on the surface. The mycelium was of the size of that of ringworm, and in some of it black pigment had been deposited. No spores had formed. I satisfied myself at the time that it had developed from the ringworm spores. On macerating the hairs the mycelial growth of trichophyton inside the hair-shafts was also found pigmented.

In the hairs deposited in the tube at the bottom of the test-glass no growth had taken place, although on maceration they were found to contain mycelium and spores of trichophyton, both containing black pigment.*

In another instance, in which the experiment was conducted in precisely the same conditions, an examination was made after the test-glass had been six days in the incubator. There was free growth of trichophyton in the hairs which had been floating on the surface of the fluid, whilst there was no growth in the hairs which were in the tube at the bottom of the glass.

In these two experiments all the hairs, both those on the surface and those at the bottom, contained trichophyton, and in each experiment both the surface and the sunk hairs were taken at the same time from the same patient, every condition being alike, except that in the one

* This patient is not the only one in whose diseased hairs the ringworm fungus was pigmented. I have found the same peculiarity in other cases, and in the affected hairs from a patch of this disease, in a black horse, I found pigmented mycelium and spores very common.

case the hairs were on the surface of the fluid, and in the other they were completely immersed in it.

It seems impossible to resist the conclusion from these and from the earlier cell experiments that trichophyton cannot grow when immersed in vitreous humour, whilst it grows freely when only moistened by it.

These experiments further suggest the view that inflammation cures ringworm by drowning the fungus. The data supplied by recent pathological researches show that serous effusion from the blood-vessels is the invariable concomitant of inflammatory action, however it is produced. When a persistent inflammatory congestion is kept up by irritants around the hair follicles, it of necessity follows that the serous effusion should make its way through the root-sheaths, whilst the inner root-sheath, and the cuticle of the hair are more or less broken up by the growth of the fungus. It is a fair inference from the experiments described in this paper that the capacity for growth in trichophyton must be destroyed by the resulting immersion in serum. Clinically and as a matter of fact, we know that this is just what takes place, and the only reason why ringworm is such a tedious disease under treatment is that the same amount of irritation by external agents does not produce the same amount of congestion in any two patients, and that a careful practitioner will always hesitate to induce such an intensity of inflammation as might injure the health of the patient or produce partial baldness by destruction of the hair follicles. *Trichophyton tonsurans*, although it grows in the epidermis of children and adults alike, and thrives in the hairs of the scalp in children, cannot, as a rule to which there is hardly any exception, live in the hairs and follicles of the scalp of adults. The explanation of this peculiarity will probably be found in the anatomical relations of the inner root-sheath and the hair, and I suggest as an hypothesis that the fungus does not penetrate between these structures in the adult because it does not find there sufficient moisture for its development.

Preparations showing the mycelium well, with the process of spore formation as it takes place within the hair-shaft, do not appear to have been often portrayed, if we may judge by the figures in ordinary medical works, most of the drawings which are found in text-books of medicine representing it imperfectly.

I found that hairs which had been macerated for several days in vitreous humour afforded excellent specimens for observation.

Good preparations of trichophyton, showing the different stages of development, are easily obtained by ordinary methods from scrapings of the epidermis in ringworm of the skin of the body, and an excellent representation of the appearances then seen is given in Cornil and Ranvier's "Manuel d'Histologie Pathologique," p. 1221.

The main conclusions regarding *Trichophyton tonsurans* which are warranted by the experiments recorded in this paper are that:—

1. It is not one of the common fungi.
2. It can be cultivated artificially when moistened by vitreous humour.
3. When covered by vitreous humour it does not grow.

The second of these formulated statements suggests whether the inability of the fungus to grow in the hairs of the scalp in adults may not be due to the firmer texture of the root-sheaths, and the consequent comparative absence of moisture between the inner root-sheath and the hair. The third explains why the fungus may be destroyed by provoking inflammation of the scalp.

DESCRIPTION OF PLATE 2.

Figure 1. Cultivation in a cell. (Two days in the incubator.)
× 750.

Figure 2. Cultivation on the surface of vitreous humour in a test-glass, showing the first appearance of spore-formation in the mycelium.
× 600.

Figure 3. Growth on the surface of vitreous humour in a test-glass, showing an early stage of spore-formation.
× 880.

Figure 4. Spores germinating. Drawn (without the camera) from a preparation in a cell the same day in which it had been placed in the incubator.

Figure 5. Two days' growth in a cell.
× 750.

Figure 6. Two days' growth in a cell.
× 750.

Figure 7.* A hair from a cultivation on the surface of vitreous humour in a test-glass. A mass of germinating and sprouting spores on a portion of the internal root-sheath which was attached to the hair is seen at the side of the hair-shaft. Buds and mycelium are sprouting from the sides of the hair. (In order to reduce the size of the drawing the centre of the hair-shaft has been left out.)
× 450.

* No attempt has been made to represent the fungus growth on the upper surface of the hair, as it lies in the preparation. The outlines were too much obscured by the thickness of the hair to enable this to be accurately done with the camera.

West Newman & Co. lith.

"On *Bacterium decalvans:* an Organism associated with the Destruction of the Hair in Alopecia areata." By GEORGE THIN, M.D. Communicated by Professor HUXLEY, Sec. R.S. Received February 19, 1881. Read March 3.

[PLATE 3.]

Although Gruby,* in the year 1843, announced that the affection of the hairy scalp known as alopecia areata (area celsi) is caused by a fungus, the parasitic theory of the disease has met with comparatively little support. If the patients on whom Gruby made his observations really suffered from this disease and not from ringworm, which in some of its forms is apt to be mistaken for it, this uncertainty is very remarkable. The fungus, if it exists, should not be difficult of observation, since it is described in his paper as consisting of a sheath of mycelium and spores which accompanies the hair to a distance of 1—3 millims. from the skin. Few competent observers have, however, been able to find a fungus in this disease, and Dr. Michelson, of Königsberg, in an able historical sketch in a recent number of "Virchow's Archiv,"† quotes with approval a statement by Pincus,‡ who avers that up to the year 1869 none of the observations which are relied on as confirming Gruby's observations will stand criticism. The fungus has been sought for chiefly by dermatologists, and in Hebra's text-book of "Skin Diseases,"§ a work of recognised standing, v. Bärensprung, Hebra, Wilson, Neumann, Bœck, Duhring, Scherenberg, and Kaposi are cited as having been unable to find it. The parasitic theory originated by Gruby was noticed less and less by authorities, the disappearance of the hair in patches from a pale uninflamed skin being attributed to a "tropho-neurosis."

Latterly, the question of parasitism has been again raised. Malassez‖ stated in a paper published in 1874 that he had found a fungus, not in the hairs, but on the surface of the epidermis of the diseased parts. There was no mycelium found, but only spores, of which he described three types:—

1. Double-contoured spores, sometimes with a bud (*bourgeon*), 4—5μ in diameter;

2. Smaller spores, 2—2·5μ large, single-contoured, some of these also with a bud;

3. Very small, under 2μ sporules, single-contoured and without buds.

* "Comptes Rendus," 1843, xvii, p. 301.

† Vol. lxxx, p. 296.

‡ "Ueber Herpes tonsurans u. Area Celsi." "Deutsche Klinik," vol. xxi.

§ "Lehrbuch der Hautkrankheiten," vol. ii, p. 150.

‖ "Archives de Physiologie Norm. et Patholog.," 1874.

Eichhorst* states that in nine cases he found spores on the diseased hairs once, between the shaft and root sheaths. There was no mycelium, and the spores were about the size of those of the *Microsporon furfur*. The descriptions given by Gruby, Malassez, and Eichhorst of his solitary case differ from each other; Gruby describing a fungus with mycelium which ensheathes the hair shaft, Malassez single spores of various sizes scattered over the epidermis, and Eichhorst large spores between the hair shaft and root sheaths.

A hypothesis of another kind has been put forward by Buchner.† Considering that the disappearance of the hair in ever-widening circles which bear no relation to the distribution of blood-vessels or nerves, without any evident cause, is best explained by the theory of parasitism, but yet acknowledging the failure of the attempts that have been made to discover the parasite, this observer asks whether the parasite may not be a bacterium, which on account of its smallness and position in the hair cannot be brought under observation. In support of this hypothesis he instances an experiment which he made. In a case of the disease he extracted hairs from the affected patch with heated forceps (so as to exclude contamination to the greatest possible extent), and placed them in a cultivating fluid. He reasoned that if there are bacteria in the hairs they will be in greater number than the bacteria introduced accidentally with the hairs, and that in the first hours of cultivation they would greatly outnumber these latter. Accordingly, he found in eight successive cultivations a bacterium which he describes as a small refractive sharply contoured particle (*Körnchen*), scarcely 0·001 millim. in diameter, with two very fine and short thread-like processes projecting from opposite poles. He remarks that this may not necessarily be the form which the presumed bacterium has in the hair, as the effect of cultivation is sometimes to alter the forms of bacteria.

The observations which are recorded in the following paper were preceded by desultory studies of hairs extracted from patients suffering from this disease during the five years preceding 1880, of which no notes were taken, my attention having been directed to the subject after the appearance of Malassez's paper in 1874.

In none of the hairs, however, which I examined did I discover a fungus. The hairs which I did not have time to examine were put away for future study, carefully folded in paper.

In examining one of the hairs which had been kept for some time, I observed flakes of a filmy substance fall away from the hair, and imbedded in this substance there were what seemed to me to be great numbers of micrococci.

From that time when examining hairs from the margin of patches

* "Virchow's Archiv," vol. lxxviii.

† "Virchow's Archiv," vol. lxxiv.

of this disease I always looked for evidences of the presence of bacteria. The difficulty of distinguishing in a fluid minute granules from micrococci or from the spore forms of rod bacteria, is so great, that it was only when the characteristic appearances of elongating spheroids or small rod-shaped bodies containing spheroidal elements, arranged linearly, or rod bacteria were observed, that the evidence of the presence of organisms was deemed conclusive. These were, however, observed sufficiently often to satisfy me that their presence was probably more than accidental, and to induce me to submit the affected hairs to various processes with the view of enabling the contents of the hair shaft to be better observed.

During the year 1880 six cases were specially utilised for this purpose, and, as in all these cases, a considerable number of hairs, in several of them a large number, were examined and submitted to methods of examination eminently fitted to display a fungus, if such were present, it may be useful to state in further confirmation of the opinions generally entertained, that in none of them any more than in those previously observed, was any fungus discovered.*

All these six cases were unmistakable examples of alopecia areata. Evidence that this was so would be out of place in this paper, but will be given in due time in a professional journal in connexion with a description of the treatment under which the disease was in all of them at once arrested.†

The treatment referred to was based on the evidence which, by this time I believed I had obtained, that the progress of the disease was due to the development of a bacterium.

In utilising these cases for the demonstration of an organism, my object was not so much to observe bacteria in fluids in which the hairs were examined, as to endeavour to find some method by which their presence could be shown in the substance of the hair. In five of the six cases I satisfied myself that this had been done. This demonstration is attended with great difficulty. In a comparatively sound hair it is very difficult to bring minute objects like bacteria under observation, and in hairs which are considerably affected the shaft is found, when prepared for examination, to be so full of pigment and other granules that it becomes very difficult to distinguish organisms amongst them, presuming these to be present.

The methods employed were the following:—

* The extent to which these investigations have been carried, more especially as regards the number of hairs examined in some of the cases, leads me to believe that those authors who have described a fungus in alopecia areata made a mistaken diagnosis, and that their cases were examples of ringworm in which the growth of the trichophyton had produced comparatively little reaction in the skin.

† As I am familiar with the disease, for the purposes of this paper my statement as regards the diagnosis may be considered sufficient.

1. The hairs when extracted were placed for a short interval in potash solution (the strength used varied from 5 to 20 per cent.); they were then washed in distilled water, and passed successively through absolute alcohol and ether. After being thoroughly subjected to the action of ether they were again placed successively in alcohol and distilled water, and were then finally mounted for examination in diluted Goadby's solution.*

The object of these manœuvres was to make the hair transparent, free it from oily particles, and finally mount it in a medium suitable for the detection and preservation of any organisms which it might contain. The method was not perfectly nor always successful, but in some instances it sufficed to show objects within the cuticle of the hair, which I believe it is justifiable to consider as bacteria.

2. The extracted hairs were at once examined in the Goadby's solution.

3. The hairs were placed successively in absolute alcohol, oil of cloves, and dammar varnish, in which they were examined.

4. Hairs kept for future examination in Goadby's solution, and in a 5 per cent. solution of carbolic acid were at convenient times, after being soaked for a little while in distilled water, subjected to the alcohol, oil of cloves, and dammar process.

In all cases precautions were taken to prevent the development of organisms after the hairs were extracted.

Attempts to show the presence of bacteria in the hairs by staining with methylaniline were defeated by the intensity with which the hair itself was stained with this dye.

The result of the examinations of a large number of hairs prepared by these methods has been to satisfy me that minute objects can be detected in them similar in size and form to those which I had recognised as organisms on the borders of freshly-extracted hairs, and preparations were obtained in which these objects were found in positions, and so arranged as to show that they were distinct from the rows and aggregations of minute granules which are found in healthy hairs.

The objects referred to were seen either as round or as elongated rounded bodies, and resembled in shape and in their refractive qualities the elements which I have described as cocci in a paper on *Bacterium fœtidum* ("Proc. Roy. Soc.," No. 205, 1880). In the preparations put up in dammar varnish these bodies were not liable to be mistaken for oily particles or crystals, which were not present in the hairs. In the preparations put up in Goadby's solution, in spite of the care which had been taken to soak the hairs in ether, oily

* The following is the formula :—Bay salt, 12 ounces; burnt alum, 6 ounces; corrosive sublimate, 15 grains; water, 1 gallon. Dissolve and filter. I have found it an excellent medium for mounting.

particles were present to such an extent as frequently to make accurate observations impossible.

In some hairs, however, this mode of preparation had produced results which were most instructive.

The effect of the potash and other treatment had been to get quit of the whole contents of the cuticle at some parts, the cuticle being then seen as a transparent membrane.

At these parts the minute objects I have described were found clustered on the inner surface of the membrane. In all the hairs in which they were found, and in all the patients, these bodies were the same in size, and refracted light in the same way. They were found frequently in pairs, the long axis of each member of the pair forming a continuous line. Sometimes three of them were found end to end with an appearance of one continuous sheath for the three. These appearances are characteristic of bacteria in development.

In seven cases in which a treatment was applied that was designed to arrest the development of organisms, and mechanically to prevent their being transported from one hair to the other, the disease at once ceased to spread. In one case, whilst the patches under treatment had been arrested, and new hairs were coming on them, two other patches had appeared unobserved on other parts of the head.

The same treatment at once arrested the growth of these new patches.

I have taken much pains to represent the size of these bodies by means of camera drawings, and I believe I have succeeded fairly well; but I confess to have found it very difficult to get the exact size. As many measurements made of the same objects agreed with each other I believe the drawings may be taken as a guarantee, both of size and shape.

In order further to ensure accuracy in this respect I obtained the kind assistance of Mr. Noble Smith, whose capacity as an accurate draughtsman in all that relates to microscopic objects is recognised and appreciated. Fig. 2 was prepared from a drawing by Mr. Smith. He determined the outlines of the hair, and drew a number of the objects (or organisms) to the size in which he saw them. The others were filled in to the scale determined by Mr. Smith. The magnifying power represented in the drawing was estimated by measuring the hair.

Clusters of the organisms were also found in dammar preparations in which the hair was found split into shreds. These shreds were sometimes so thin that the objects which I am describing were seen with much distinctness.

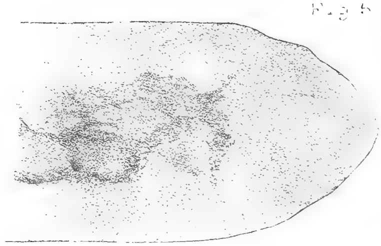
The order of development of the organisms, or the different stages of their action in breaking up the hair shaft, I believe to be indicated by the appearances which I have figured in the drawings. In fig. 1 there is represented what I believe to be an early stage, the earliest which I have observed. A cluster of bacteria is seen on the surface of the hair shaft, but under the cuticle of the hair, whilst on the side of the hair others are seen embedded in granular *débris*, probably remains of the inner root sheath. The shaft of the hair is unbroken.

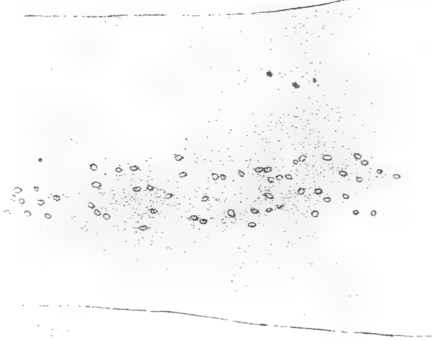
In fig. 2 great numbers of bacteria are seen near the root of a hair. By regulation of the fine adjustment the position of the bacteria could be accurately made out. A considerable length of the root sheath had come away with the hair, completely investing it. The bacteria were found in a circular layer between the root sheath and the shaft of the hair. They had neither penetrated the root sheath nor the shaft. Fig. 4 indicates the position of the organisms as they are seen when the centre of the hair is brought into focus: the drawing being on too small a scale to show the individual bacteria their position has been shown by dark shading. In fig. 5 the dark shading shows the position of the bacteria when the lower surface of the hair is brought into focus. By comparing these three figures with each other, the arrangement of the bacteria becomes apparent. In fig. 6 part of a hair is represented in which the removal of the substance of the hair shaft has shown a number of organisms disseminated over the inner surface of the cuticle. They were traced towards the thick unemptied part of the hair, in which they became lost in a thick granular mass. In fig. 7 a hair is shown in which organisms were found immediately under the cuticle.

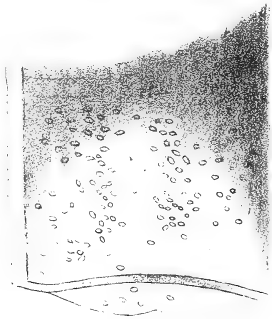
I infer from all these appearances that the bacterium penetrates downwards between the internal root sheath and the shaft. Towards the root of the hair it penetrates the hair substance, and as it multiplies it ascends upwards in the substance of the hair. The breaking up, loosening, and disappearance of the hair is to be attributed to the disorganisation of the hair substance by the growing organisms, for it is impossible to suppose that a free development of bacteria could take place in the shaft of a hair without the substance being decomposed and its integrity destroyed.

This is the inference which it seems to me follows naturally from the detection of organisms in the diseased hairs in alopecia areata. It might be alleged that it has not been shown that the composition of the hair is not altered by some supposed error of nutrition, and that bacteria find in these abnormal hairs a soil in which they can thrive. No such alleged nutritive change has ever been shown to exist, and I believe that the existence of an object of a definite size and form having the characteristic appearance of a bacterium, and now ascertained for a certain although a small number of cases, will afford to workers in similar fields strong presumptive evidence that its presence is the key to the mystery in which the disease has been shrouded. In

Fig. 4.







West Newman & Co. lith.

extracting hairs for examination I took them from a considerable breadth of margin, and as the proportion of the hairs examined which showed any change or evidence of organisms was small, it is probable that these are present only in a narrow zone, and that after a hair is once attacked development takes place rapidly and the hair soon falls.

It may be well to divide the statements made in this paper into two heads; those which relate to ascertained facts, and those which relate to a theory of the causation of alopecia areata, which I believe is sustained by these facts:—

1. The facts are that minute bodies of definite and fixed shape and size are found in and on the hairs in alopecia areata. These bodies are distinct from the granular elements present in hairs, and are neither oily particles nor crystals. They are of the size and shape, and have the refractive qualities of bacteria. When present in small numbers on the shaft the hair is entire, whilst within some hairs much affected by the disease they were found in great numbers.

2. The theory is that these bodies are bacteria, and that the disappearance of the hair is due to a breaking up of the hair shaft by the multiplication in it of the organisms.

As I believe it is desirable to give to definite objects like those which I have described a name which will mark their association with the theory I have founded on them, and as I am myself satisfied as to their nature, I suggest the term *Bacterium decalvans* as a convenient designation.

DESCRIPTION OF PLATE 3.

Figure 1. Case of S. B. A small group of organisms on the shaft of the hair, under the cuticle. Others are seen scattered in a granular mass which is adherent to the hair.
(Camera drawing.) × 600.

Figure 2. Case of I. F. Organisms between the root-sheath and the shaft of the hair near the root. (Drawn by Mr. Noble Smith.)
× about 470.

Figure 3. Organisms from the group shown in fig. 2, more highly magnified.
(Camera drawing.) × 560.

Figure 4. The hair shown in fig. 2, the focus being now in the axis of the hair. The position of the organisms is indicated by the dark shading.

Figure 5. The hair shown in fig. 2 when the focus is carried down to the under surface, the position of the organisms being again indicated by the dark shading.

Figure 6. Case of S. B. In a part of the hair from which the substance of the hair-shaft has disappeared and the cuticle left empty, organisms are seen lying on the internal surface of the cuticle.
(Camera drawing.) × 880.

Figure 7. Case of N. S. Organisms on the shaft and beneath the cuticle.
(Camera drawing.)

January 12, 1882.

THE PRESIDENT in the Chair.

The Right Hon. Sir George William Wilshere Bramwell, and the Right Hon. Henry Fawcett, whose certificates had been suspended as required by the Statutes, were balloted for and elected Fellows of the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On the Results of Recent Explorations of Erect Trees containing Reptilian Remains in the Coal Formation of Nova Scotia." By J. W. Dawson, C.M.G., LL.D., F.R.S., &c. Received October 11, 1881.

(Abstract.)

The explorations referred to were carried on chiefly in the beds at Coal Mine Point, South Joggins, Nova Scotia; and their object was to make an exhaustive examination of the contents of erect trees found at that place and containing remains of Batrachians and other land animals.

A detailed section is given of the beds containing the erect trees in question, with lists of their fossil remains. The most important part of the section is the following:—

Sandstone with erect *Calamite* and *Stigmaria* roots....................................	6 ft. 6 in.
Argillaceous sandstone, *Calamites*, *Stigmaria*, and *Alethopteris Cuchitica*......................	1 ,, 6 ,,
Gray shale, with numerous fossil plants, and also *Naiadites*, *Carbonia*, and fish scales..........	2 ,, 4 ,,
Black coaly shale, with similar fossils..........	1 ,, 1 ,,
Coal, with impressions of *Sigillaria* bark	0 ,, 6 ,,

On the surface of the coal stand many erect *Sigillariæ*, penetrating the beds above, and some of them nearly three feet in diameter at the base and nine feet in height. In the lower part of many of these erect trees there is a deposit of earthy matter, blackened with carbon and vegetable remains, and richly stored with bones of small reptiles, land snails, and millipedes. Detailed descriptions of the contents of these

trees are given, and it is shown that on decay of the woody axis and inner bark they must have constituted open cylindrical cavities, in which small animals sheltered themselves, or into which they fell and remained imprisoned. These natural traps must have remained open for some time on a subaerial surface.

In all twenty-five of these erect trees had been discovered and extracted, and the productive portions of them preserved and carefully examined. Of these, fifteen had proved more or less productive of animal remains. From one no less than twelve reptilian skeletons had been obtained. In a few instances, not only the bones, but portions of cuticle, ornamented with horny scales and spines, had been preserved.

The Batrachians obtained were referred to twelve species in all. Of these two were represented so imperfectly that they could not be definitely characterised. The remaining ten were referable to the two family groups of *Microsauria* and *Labyrinthodontia*.

The *Microsauria* are characterised by somewhat narrow crania, smooth cranial bones, simple or non-plaited teeth, well-developed limbs and ribs, elongated biconcave vertebræ, bony scales and plates on the abdomen, and horny scales, often ornate, on the back and sides. They show no traces of gills. The species belonging to this group are referred to the genera *Hylonomus*, *Smilerpeton*, *Hylerpeton* and *Fritschia*. The characters of these genera and of the several species are given in detail and illustrated by drawings and photographs, including microscopic delineations of the teeth of all the species, with their internal structure and the microscopic structure of their bones, as well as representations of their cuticular ornamentation and armour.

The Labyrinthodonts are represented by only two species of *Dendrerpeton*, which are also described and delineated.

About half of the reptilian species described are new, and those previously described from fragmentary remains are now more fully characterised, and their parts more minutely examined.

The invertebrate animals found are three species of land snails and five of myriapods, besides specimens supposed to represent new species of myriapods and insect larvæ, not yet fully examined, and which have been placed in the hands of Dr. Scudder, of Cambridge, U.S.

The memoir, consisting in great part of condensed descriptions of the facts observed, does not admit of much abridgment, and cannot be rendered fully intelligible without the accompanying plans, sections, and drawings. It closes with the following general statement:—

"The negative result that, under the exceptionally favourable conditions presented by these erect trees, no remains of any animals of higher rank than the *Microsauria* and *Labyrinthodontia* have been found deserves notice here. It seems to indicate that no small animals of higher grade inhabited the forests of Nova Scotia at the period in question; but this would not exclude the possibility of the existence of higher animals of a larger size than the hollow trees were capable of receiving. Nor does it exclude the possibility of higher animals having lived contemporaneously in upland situations remote from the low flats to which our knowledge of the coal formation is for the most part confined. It is to be observed also that as some of the reptilian animals are represented only by single specimens, there may have been still rarer forms, which may be disclosed should other productive trees be exposed by the gradual wasting of the cliff and reef."

II. "On the Variation of the Electric Conductivity of Glass with Temperature, Density, and Chemical Composition." By THOMAS GRAY, B.Sc., F.R.S.E. Communicated by Professor Sir WILLIAM THOMSON, F.R.S. Received December 28, 1881.

(Abstract.)

In this paper the results of the continuation of a series of experiments, some preliminary results of which were published in the "Phil. Mag." for October, 1880, are given. The experiments were performed in the Physical Laboratory of the Imperial College of Engineering, Tokio, Japan.

In the preliminary experiments it was found that the conductivity of glass increased with the temperature, following a similar law to that found to hold for other highly insulating substances. It was also found that the effect of successive heatings and coolings was to diminish the conductivity. Further experiments on this subject show that although the diminution of conductivity here referred to sometimes occurs, it does not always occur, and does not seem to do so when the glass is newly manufactured. Reference is made to preliminary experiments on the effect of time on the electric conductivity of glass, the results of which indicate an increase in conductivity with time.

The subject of the main part of the paper is an account of experiments on the relation between the electric conductivity of glass and its density and chemical composition. A large number of specimens of lime glass were examined, but, as was to be expected in this case, no marked connexion between electrical quality and density could be observed. It was found, however, on analysing a few specimens, that the composition of those which had a high conductivity differed considerably from that required to form an exact chemical compound, while those which had a low conductivity had a composition agreeing more or less closely with that required for a trisilicate of potash and lime, or a mixture of potash, lime, and soda-lime trisilicates.

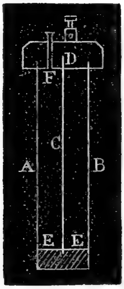
A few specimens of lead or flint glass were examined in the same way, and in this case a very marked connexion between electric conductivity and density was observed. This result was, however, no doubt due to the fact that the density of this kind of glass gives an indication of its chemical composition. In all the specimens examined it was found that the higher the density the lower the conductivity. The highest density reached, however, was that in the case of a Thomson's electrometer jar, which had a density of 3·172. On examining these specimens for chemical composition it was found that the electrometer jar contained almost exactly the proper amount of lead and potash to form a trisilicate of potash and lead. It appears likely, therefore, that the electric conductivity of glass is lowest when it is an exact chemical compound. It will be interesting to learn from future experiments if still more dense glass has a higher conductivity, and if the conductivity passes a minimum at the point where the pure silicate is reached.

The author has to express his great obligation to his colleague, Dr. Edward Diver, in whose laboratory and under whose superintendence the chemical analyses of the specimens of glass were made.

III. "On a New Electrical Storage Battery. (Supplementary Note.)" By HENRY SUTTON. Communicated by THE PRESIDENT. Received January 3, 1882.

The new cell consists of a flat copper case, of the same shape as a Grove's cell; it has a lid of paraffined wood, from which hangs a plate of lead amalgamated with mercury, the lower part of the lead plate being held in a groove in a slip of paraffined wood resting on the bottom of the copper case: through the lid a hole is bored for the introduction of the solution, which consists of a solution of cupric sulphate, to which is added one-twelfth of hydric sulphate; the presence of this free sulphuric acid improves the cell at once.

The following sectional sketch shows the arrangement:—



AB. The outer flat copper case.

C. Plate of amalgamated lead held in grooves in the cap D and the slip E.

F shows the hole in the cap through which the solution is introduced, and by the introduction of a glass tube through this hole the state of the charge is seen by observing the colour; the interior surface of the case forms the negative, and the amalgamated lead the positive electrode.

January 19, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read :—

I. "On certain Definite Integrals." No. 10. By W. H. L. RUSSELL, F.R.S. Received December 31, 1881.

Let $a_0+a_1x+a_2x^2+a_3x^3+a_4x^4=\alpha+\beta(\mu+\nu x+\rho x^2)+\gamma(\mu+\nu x+\rho x^2)^2$. Then we find the condition

$$8a_1a_4^2+a_3^3-4a_2a_3a_4=0,$$

together with the equations—

$$\gamma\rho^2=a_4, \qquad 2a_4\nu=\rho a_3, \qquad \beta\nu+2\gamma\mu\nu=a_1,$$

when there are three equations connecting the five quantities β, γ, μ, ν, ρ.

Under these conditions we shall have—

$$\int_b^a dx\epsilon^{a_0+a_1x+a_2x^2+a_3x^3+a_4x^4}=\int_{\mu+\nu b+\rho b^2}^{\mu+\nu a+\rho a^2}\frac{dz\,.\,\epsilon^{\alpha+\beta z+\gamma z^2}}{\sqrt{4\rho(z-\mu)+\nu^2}} \quad . \quad . \quad . \quad (220).$$

In the same way, if

$$a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6$$
$$=\alpha+\beta(\mu+\nu x+\rho x^2)+\gamma(\mu+\nu x+\rho x^2)^2+\delta(\mu+\nu x+\rho x^2)^3,$$

we have similarly—

$$\int_b^a dx\epsilon^{a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6}=\int_{\mu+\nu b+\rho b^2}^{\mu+\nu a+\rho a^2}\frac{dz\,.\,\epsilon^{\alpha+\beta z+\gamma z^2+\delta z^3}}{\sqrt{4\rho(z-\mu)+\nu^2}} \quad . \quad (221).$$

There will be six equations connecting the quantities a_1, a_2, a_3, a_4,

a_5, a_6, with β, γ, δ, μ, ν, ρ; I have not observed that these equations lead to an equation of condition between a_1, a_2, . . . *

This transformation will apply equally well to all integrals of the form—

$$\int dx\phi(a_0+a_1x+a_2x^2+a_3x^3+a_4x^4) \quad . \quad . \quad . \quad . \quad (222),$$

and $$\int dx\phi(a_0+a_1x+a_2x^2+a_3x^3+a_4x^4+a_5x^5+a_6x^6) \quad . \quad . \quad (223).$$

If we consider the integrals

$$\int_0^\alpha d\theta \sin(a+b\theta+c\theta^2+\ldots\alpha\theta^n) \quad . \quad . \quad . \quad . \quad (224),$$

and $$\int_0^\alpha d\theta \cos(a+b\theta+c\theta^2+\ldots\beta\theta^n) \quad . \quad . \quad . \quad . \quad (225),$$

where α is not infinite, as it is in Fresnel's integrals, we must proceed by expansion.

Let $\Theta=a+b\theta\ldots e\theta^n$, $\quad u=\sin\Theta$, $\quad v=\cos\Theta$,

$$\frac{du}{d\theta}=\frac{d\Theta}{d\theta}\cdot v, \qquad \frac{dv}{d\theta}=-\frac{d\Theta}{d\theta}\cdot u,$$

$$\frac{d^2u}{d\theta^2}=\frac{d^2\Theta}{d\theta^2}v+\left(\frac{d\Theta}{d\theta}\right)u, \qquad \frac{d^2v}{d\theta^2}=-\frac{d^2\Theta}{d\theta^2}u-\frac{d\Theta^2}{d\theta^2}v.$$

Proceeding in this manner, and remembering that when $\theta=0$, $\sin\Theta=\sin a$, $\cos\Theta=\cos a$, we are able to develope u and v with great facility, and so obtain the integrals.

The following method may be very generally applied. Let

$$\phi(x)=A_0+A_1\left(\frac{x-a}{x+a}\right)+A_2\left(\frac{x-a}{x+a}\right)^2+\ldots$$

where (a) is an arbitrary quantity. Then we shall have—

$$\int dx\phi(x)=\int\frac{dx}{(x+a)^2}(x+a)^2\phi(x)$$

$$=4a^2\int\frac{dx}{(x+a)^2}\left\{1+2\left(\frac{x-a}{x+a}\right)+3\left(\frac{x-a}{x+a}\right)^2+\ldots\right\}$$
$$\left\{A_0+A_1\frac{x-a}{x+a}+A_2\left(\frac{x-a}{x+a}\right)^2+A_3\left(\frac{x-a}{x+a}\right)^3+\ldots\right\}$$

$$=2a\left\{B_0\cdot\frac{x-a}{x+a}+\frac{B_1}{2}\left(\frac{x-a}{x+a}\right)^2+\frac{B_2}{3}\left(\frac{x-a}{x+a}\right)^3+\ldots\right\} \quad . \quad . \quad . \quad . \quad (226),$$

where $B_0=A_1$, $B_1=A_1+2A_0$, $B_2=A_2+2A_1+3A_0\ldots$

The calculation of B_0, B_1 . . . is very easy. Form by addition the

* Jan. 23. But Mr. Spottiswoode has discovered two conditions, which will, I hope, be inserted in the next paper on the subject.

series A_0, A_0+A_1, $A_0+A_1+A_2+\ldots$ Then by a second addition we have A_0, A_1+2A_0, $A_2+2A_1+3A_0$, or B_0, B_1, B_2, ...

Moreover, if the series A_0, A_1, A_2, &c., is convergent, the series B, B_1, B_2, &c., is also convergent, because

$$\frac{B_{n+1}}{B_n}=\frac{A_{n+1}\quad+2A_n\quad+3A_{n-1}+4A_{n-2}+\ldots}{A_n+2A_{n-1}+3A_{n-2}+4A_{n-1}+\ldots},$$

and if A_{n+1} is in the limit less than A_n, A_n less than A_{n-1} ... B_{n+1} must in the limit be less than B_n.

Hence if the limits are greater than a, and the difference between either of them and a small when compared with (a), we shall have in many cases excellent convergence.

This method of converging to the value of definite integrals is useful in dynamical problems. Another is as follows.

Let $$\phi(x)=a+bx+cx^2+ex^3+\ldots rx^n=z^2,$$

then $$\phi'(x)\frac{dx}{dz}=2z,$$

$$\phi''(x)\frac{dx^2}{dz^2}+\phi'(x)\frac{d^2x}{dz^2}=2,$$

$$\phi'''(x)\frac{dx^3}{dz^3}+3\phi''(x)\frac{dx}{dz}\cdot\frac{d^2x}{dz^2}+\phi'(x)\frac{d^3x}{dz^3}=0,\ \&c.$$

When $z=0$, x is one of the roots of $a+bx+cx^2+\ldots+rx^n=0$; call it (α). Then

$$\frac{dx}{dz}=0,\qquad \frac{d^2x}{dz^2}=\frac{2}{\phi'(\alpha)},$$

$$\frac{d^3x}{dz^3}=0,\qquad \frac{d^4x}{dz^4}=-\frac{12\phi''(\alpha)}{(\phi'\alpha)^3}.$$

Hence $$x=\alpha+\frac{z^2}{\phi'\alpha}-\frac{\phi''\alpha}{(\phi'\alpha)^3}\cdot\frac{z^4}{2}+\ldots,$$

$$\int x\,dz=\alpha z+\frac{z^3}{3\phi'\alpha}-\frac{\phi''(\alpha)}{(\phi'\alpha)^3}\cdot\frac{z^5}{2\cdot5}+\ldots$$

But $$\int x\,dz=xz-\int z\,dx.$$

Hence $\int dx\sqrt{a+bx+cx^2+ex^3+\ldots+ex^n}$

$$=xz-\left\{\alpha z+\frac{z^3}{3\phi'\alpha}-\frac{\phi''\alpha}{(\phi'\alpha)^3}\cdot\frac{z^5}{2\cdot5}+\ldots\right\}\quad.\quad(227).$$

The limits are arbitrary; but the series evidently requires that $\phi'(\alpha)$ should be considerable.

Since $$\int_0^1 dx\,x^{n-1}=\frac{1}{n},$$

$$\int_0^1 dx(1-x)x^{n-1}=\frac{1}{n(n+1)},$$

$$\int_0^1 dx(1-x)^2x^{n-1}=\frac{1\,.\,2}{n(n+1)(n+2)},$$

$$\int_0^1 dx(1-x)^3x^{n-1}=\frac{1\,.\,2\,.\,3}{n(n+1)(n+2)(n+3)},$$

&c. = &c., we have, if $\phi(\theta)=A_0+A_1\theta+A_2\theta^2+\ldots$,

$$\int_0^1 \phi(1-x)dxx^{n-1}=\frac{A_0}{n}+\frac{A_1}{n(n+1)}+\frac{1\,.\,2\,.\,A_2}{n(n+1)(n+2)}+\text{ \&c. } \quad . \quad (228).$$

This formula is most useful when n is very large, or when (n) is very small. Suppose $n=100$, then the tenth term is less than

$$\frac{A_9}{60,000,000,000,000},$$

and after this the terms continue to diminish, though not so rapidly.

When n is very small, we shall come to an integer (r) which does not differ sensibly from $n+r$, and therefore we are able to write the integral:—

$$\int_0^1 \phi(1-x)dxx^{n-1}=\frac{A_0}{n}+\frac{A_1}{n(n+1)}+\frac{1\,.\,2\,.\,A_2}{n(n+1)(n+2)}+\ldots$$
$$+\frac{1\,.\,2\,.\,3\ldots r}{n(n+1)\ldots(n+r)}(A_r+A_{r+1}+A_{r+2}\ldots)$$
$$=\frac{A_0}{n}+\frac{A_1}{n(n+1)}+\frac{1\,.\,2\,.\,A_2}{n(n+1)(n+2)}+\frac{1\,.\,2\,.\,3\,.\,A_3}{n(n+1)(n+2)(n+3)}+\ldots$$
$$+\frac{1\,.\,2\,.\,3\ldots r}{n(n+1)\ldots(n+r)}(\phi(0)-A_0-A_1\ldots-A_{r-1})\,.\,(229).$$

In the same way we are able to find:—

$$\int_0^1 \phi(1-x)dxx^{n-1}(\log_\epsilon x)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (230)$$

$$\left(\text{since} \qquad \int_0^1 x^{n-1}(\log_\epsilon x)^2=\frac{2}{(n+1)^3}\right);$$

also

$$\int_0^1 \chi(1-x)dxx^{n-1}\phi(\log_\epsilon x) \quad . \quad . \quad . \quad . \quad . \quad (231).$$

$$\int_0^1 dxx^{n-1}\phi(1-x,\log_\epsilon x) \quad . \quad . \quad . \quad . \quad . \quad . \quad (232).$$

We must, however, observe that the functions involving $\log x$ are supposed convergent, whatever the value of $\log_\epsilon x$, when expanded.

In a similar way we obtain

$$\int_0^\pi d\theta\theta \sin\theta\phi(\sin^2\theta)\cos^{2r}\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad (233).$$

January 19, 1882.—From formula (226) it immediately follows that—

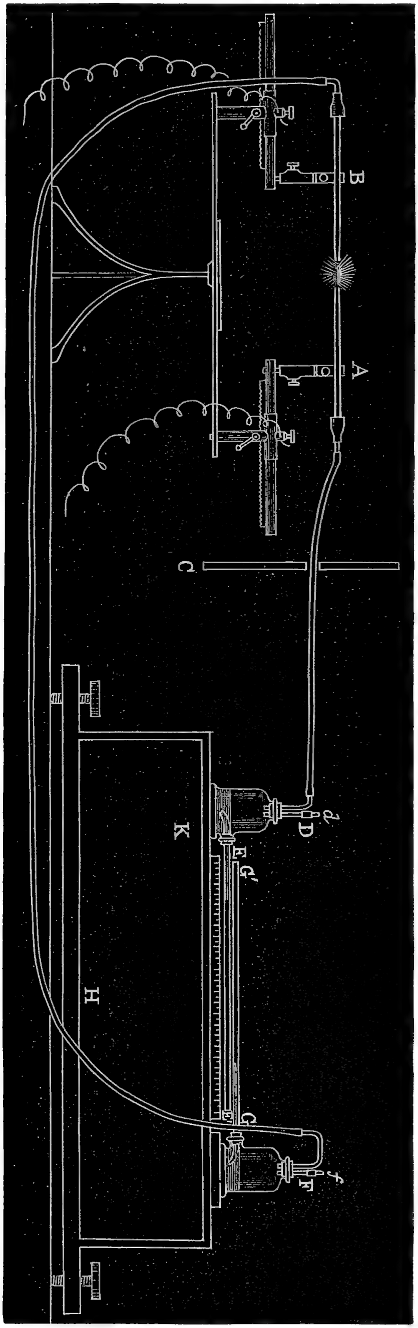
$$\int_\beta^\alpha dx\phi(x) = 2\beta\left\{B_0\frac{\alpha-\beta}{\alpha+\beta} + \frac{B_1}{2}\left(\frac{\alpha-\beta}{\alpha+\beta}\right)^2 + \ . \ . \ . \ \right\}$$

II. "Manometric Observations in the Electric Arc." By Professor Dewar, M.A., F.R.S. Received January 14, 1882.

The experiments recorded in my former paper, entitled "Studies on the Electric Arc,"* together with the numerous observations made conjointly with Professor Liveing on the spectrum of the arc discharge between carbon electrodes in different gases, led me to ascertain if the interior of the gaseous envelope of the ordinary arc showed any peculiarities of pressure. Pressure might be caused by the motion of the gas particles, the transit of material from pole to pole, electric action, or indirectly by chemical combinations taking place in the arc. As any effect due to the above causes must necessarily be very small, a delicate manometer capable of measuring easily the $\frac{1}{100}$th of a millimetre of water pressure had to be employed. The records of such an instrument in the present series of experiments, are complicated by the indirect action of the hot currents of air passing the poles, and the irregularities in the steadiness of the arc which undoubtedly cause marked variations of pressure; yet by multiplying and varying the conditions of the experiments, it is possible to eliminate these secondary effects and secure reliable results. The general appearance of the apparatus used is shown in the diagram. A and B are two hollow carbons, similar to those I formerly employed in the separation of cyanogen from the arc.† They must be free from all porosity before they can be used in the experiments to be detailed, and the drilled hole should not be less than 3 millims. in diameter. In order to fill up minute apertures in the carbons, and render them non-porous, they are placed in a porcelain tube and heated to a white heat in a current of coal-gas saturated with vapour of benzole. This treatment causes the deposition of a layer of dense metallic carbon over the surface of the tubes which renders them capable of withstanding a considerable interior pressure of air or other gas without exhibiting leakage. The hollow poles are connected by means of tubing

* "Proc. Roy. Soc.," vol. 30, p. 85.

† "Proc. Roy. Soc.," vol. 29, p. 188.


B
A
C
d
D
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G′
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f
F

with the two manometers. Two glass cylinders, ED and GF, 50 millims. in diameter, have each a uniform horizontal tube open at both ends, 2 millims. in diameter, marked GG′ and EE′, passing through the corks E and G, fitted in side apertures. When fluid was added to a fixed level, these vessels constituted the manometers. The tubes leading from the hollow poles have been made of metal or thick india-rubber, and to prevent heating of the tubes and manometer by radiation from the arc, they have been carefully guarded by hollow tin screens (shown at C) through which a current of water flowed continuously. The lengths of tube between the manometers and poles have been varied, and in some cases the tube made into a spiral form has been immersed in water so as to guard against unequal heating. The little glass stoppers marked D*d* and F*f* were convenient for the alteration of the zero point by the addition or withdrawal of fluid from the vessels ED and GF. In the experiments water, ether, and alcohol have been used in the manometers, but the largest number of the experiments have been made with ether. This fluid is most convenient from its mobility, and the only precautions to be taken are to use plain cork stoppers instead of india-rubber, and to have a considerable length of tube between the manometers and the arc. In the diagram K is a millim. scale divided on glass, and H represents a levelling stand on which the apparatus is placed. By careful levelling and the use of ether 1 millim. of motion of the fluid in the horizontal tube may be made to correspond to about the 250th of a millim. of water pressure. In the present investigation as the absolute value of the pressure is not so important as the general variation, I have not thought it advisable to give other than relative records taken with the same instrument at different times; it is quite possible, however, to get absolute values of very small pressures by means of this instrument, and I have satisfied myself of its accuracy by measuring a series of pressures of soap bubbles of different sizes, which confirm the previous observations of Plateau that the internal pressure varies inversely as the diameter of the bubble.

When the arc passes between two pointed carbon poles it assumes two very different forms; in one case the envelope of the intensely-heated gaseous materials is well defined, almost spherical in appearance, surrounding the whole of the end of the positive pole, but touching the negative only at a single point, without showing that close adhesion to the pole which is so characteristic of the layer of gas at the positive. At other times the arc is very unsteady, noisy with apparent blasts of green flame-looking ejections, which generally arise from the positive pole. These blasts are invariably associated with a great increase of intensity in the hydrocarbon and cyanogen spectrum. While the arc is in this unstable condition manometric observations are impossible, as the small area of the carbon tube is rarely completely covered by the arc, so that the manometers often record neither positive nor negative pressures during the discharge. The effect of the hot poles on the registration of the manometers is to produce a small negative pressure when the arc has stopped, due to the passage of currents of hot air. Many experiments were made to ascertain if a local heating of the carbon tube caused any permanent pressure. This was carefully tested by taking the arc at right angles to a carbon tube placed in a block of magnesia so as to raise the middle of the tube to the highest possible temperature. Under these conditions the manometer connected with the hollow carbon remained perfectly steady, whether the tube was made the positive or negative pole of the battery. This experiment also showed that repulsion of the inclosed gas in the tubes through an electric charge, had no effect on the manometer. During the maintenance of the *steady arc*, the manometer connected with the positive pole exhibits a *fixed increase of pressure*, corresponding to a motion of the fluid in the horizontal tube of the manometers employed, of from 50 to 150 millims., which is equivalent to from 1 to 2 millims. of vertical water pressure, in different experiments and under varied conditions. The manometer connected with the negative pole shows no increase of pressure, but rather on the average a diminution.

When the arc begins to emit a hissing sound, the pressure on the positive pole instantly diminishes, and when blasts are ejected from the positive in the direction of the negative, the negative manometer which had stood at zero before showed a marked increase of pressure. If a commutator is placed in the circuit, so as to quickly reverse the direction of the original current, the arc is not broken, but the manometers immediately record a reverse action. In order to equalise the temperature of the poles to some extent, the arc was taken in the middle of a block of magnesia, but the same results were observed; the pressure is generally smaller in the hot crucible than it is in air. When the crucible gets highly heated and filled with metallic vapours, the arc will pass a distance of more than an inch, and in this condition the shorter the arc the greater the pressure. It was found advisable in these experiments to use a negative pole which had a sharp conical termination, otherwise the form of the arc in the block of magnesia was very irregular, owing to the high conductivity of the hot walls of the crucible. When the poles are brought into contact in the magnesia crucible, the pressure at the positive instantly falls.

Whether air, carbonic oxide, or nitrogen filled the manometer and carbon tubes the results were invariably the same. The chief experiments have all been made with the Siemens machine, but a 70-cell Grove's battery produced the same results. The use of the horizontal arc is a matter of convenience, as in this condition the manometers are least affected by air currents, but the same general action may be observed by the use of vertical poles. A thin carbon spatula placed in front of the end of the positive pole at once lowered the positive pressure of the manometer. This experiment does not prove much, as the carbon diaphragm causes a noisy and unsteady arc until a minute hole is pierced by the current. It is probable that the diminution of pressure may be due to the instability of the arc. In the same way the action of the magnet on the arc causes an instant reduction of the positive pressure by withdrawing the arc from completely covering the end of the carbon tube, so that this action must be regarded as an indirect one. A small carbon tube connected with a manometer was inserted into the arc, passing between two solid carbons, so as to take a section at right angles to the passage of the current. In this condition the arc is apt to be irregular in shape, and to pass rather between three poles than two, but the average records point to an increase of pressure in this position also. When the negative carbon tube is about 1 millim. in diameter, and the point sharp and the tube short, so as to diminish any air friction, the negative pole manometer seems also to give a positive pressure. The intermittent Siemens arc shows an increase of pressure at both poles.

It appears from the above experiments that the interior of the gaseous envelope of the electric arc always shows a fixed permanent pressure, amounting to about a millimetre of water above that of the surrounding atmosphere. This looks as if the well-defined boundary of the heated gases acted as if it had a small surface tension. This pressure may be due to various causes: motion of the gas particles under the conditions, transit of material from pole to pole, or a succession of disruptive discharges; and a more elaborate investigation will have to be made before the origin of the excess of pressure can be clearly defined.

January 26, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "On a Series of Salts of a Base containing Chromium and Urea. No. 1." By W. J. SELL, M.A., F.I.C., Demonstrator of Chemistry in the University of Cambridge. Communicated by Professor G. D. LIVEING, F.R.S. Received January 13, 1882.

Various compounds of urea with metallic salts and oxides have been described by Werther and Liebig. Some of these are suggestive of an analogy between urea and ammonia, while others seem altogether anomalous. The following account of some chromium compounds of urea may help to throw some light on the nature of such compounds, for they appear to show that a very definite base is formed by a combination of urea with chromium.

When powdered and carefully dried urea is moistened with chromyl dichloride, and the mixture vigorously shaken, the temperature rises considerably, and on treating the resulting mass with water, there remains undissolved, a green crystalline powder. The nature of the green salt thus obtained is at present under investigation. It is insoluble in alcohol, ether, and chloroform. It dissolves in hot water with decomposition, another salt separating out as the liquid cools in brilliant olive-green needles, which by a second crystallisation is obtained in a pure state. The examination of this body showed it to be the dichromate of a base containing the elements of urea and chromium, and to have the formula

$$\{(CON_2H_4)_{12}Cr_2\}(Cr_2O_7)_3 3H_2O.$$

The dichromate thus obtained is sparingly soluble in cold, more freely in hot water, and is decomposed by boiling the solution. Its aqueous solution gives green crystalline precipitates with platinic chloride and potassium ferrocyanide, but none with ammonia.

The following results were obtained on analysis :—

The numbers given refer to the dried salt, unless expressly stated to the contrary.

Theory.			Analysis.											
		Percentage.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
C_{12}	144	9·76	10·16	10·05	9·94	9·85	9·64							
H_{48}..........	48	3·25	3·39	3·55	3·55	3·43								
N_{24}	336	22·77	..	..	..	..	23·40	22·17						
$(CrO_3)_6$	602·4	40·83	..	..	..	..	..	..	40·81	40·73	41·11			
O_{15}	240	16·29	..	..	..	..	..	..	..	..	..	..	..	..
Cr_2	104·8	7·10	..	..	..	..	..	..	..	..	..	7·44	7·24	
	1475·2	100·00												
$3H_2O$........	54	3·53	..	..	..	..	..	..	..	..	..	..	..	3·63
	1529·2													

1. ·5531 grm. gave on combustion in oxygen ·2061 CO_2 and ·169 H_2O.

2. ·32175 grm. gave on combustion in oxygen ·11865 CO_2 and ·1029 H_2O.

3. ·3262 grm. gave on combustion in oxygen ·1189 CO_2 and ·1045 H_2O.

4. ·4147 grm. gave on combustion in oxygen ·1499 CO_2 and ·1281 H_2O.

5. ·0541 grm. gave by Gottlieb's process very nearly equal volumes of CO_2 and N, weighing ·01919 and ·01267 respectively.

6. ·35065 grm. gave by Dumas' process 62 cub. centims. nitrogen at 0° C. and 760 millims.

7. ·324 grm. dissolved in water, excess of KI and HCl added, and the iodine titrated with thiosulphate, required 40 cub. centims., each cub. centim. thiosulphate = ·00306 CrO_3.

8. ·5253 grm. precipitated by mercurous nitrate gave ·1628 grm. Cr_2O_3.

9. ·9317 grm. precipitated by mercurous nitrate gave ·2915 grm. Cr_2O_3.

10. The filtrate from ·5253 grm. after precipitation with mercurous nitrate gave, when evaporated and ignited, ·1011 grm. Cr_2O_3.

11. The mean of three concordant experiments gave on ignition 41·62 per cent. Cr_2O_3. Deducting from this the Cr existing as CrO_3, gives 10·56 per cent. Cr_2O_3 or 7·24 per cent. Cr.

12. ·4985 grm. crystallised salt (dried by pressure between bibulous paper) lost ·0181 grm. H_2O in vacuo over sulphuric acid, and no further loss at 105° C.

The Chloroplatinate.

When a hot solution of the dichromate is mixed with a solution of platinic chloride, and the mixture allowed to cool, the chloroplatinate crystallises out in long green silky needles. The compound is moderately soluble in hot, but very sparingly in cold water. The sparing solubility in cold water was made use of in preparing the bulk of this salt from washings and drainings from other compounds. After one or two crystallisations from hot water, the compound is obtained in a state of purity. The examination of the body led to the formula

$$\{(CON_2H_4)_{12}Cr_2\}(PtCl_6)_3 2H_2O$$

being assigned to it.

The following results were obtained on analysis:—

The numbers given refer to the dried compound unless stated to the contrary.

1. ·8698 grm. gave on combustion ·2207 CO_2 and ·2008 H_2O.
2. ·95362 grm. „ „ ·2331 CO_2 and ·22662 H_2O.

3. ·1383 grm. by Gottlieb's process gave volumes of CO_2 and N (nearly equal) weighing ·034986 grm. and ·0224591 grm. respectively.

4. ·09505 grm. by Gottlieb's process gave volumes of CO_2 and N (nearly equal) weighing ·0252056 and ·0154869 respectively.

5. ·2071 grm. fused with pure NaHO, acidified with HNO_3, and titrated with $AgNO_3$, using ferric sulphocyanate as indicator, required 17·85 $\frac{N}{10}AgNO_3$ solution.

6. ·3471 grm. burnt in a current of air, the chlorine caught by a column of pure lime and estimated gravimetrically, gave ·428 grm. AgCl.

7. ·3208 grm. ignited, the mixture of platinum and chromic oxide dissolved, gave ·09135 Pt determined as double salt with NH_4Cl and ·02364 grm. Cr_2O_3 from filtrate by precipitation with ammonia.

8. ·07973 grm. acidified with HCl, the Pt precipitated by H_2S, and the Cr_2O_3 in filtrate after decomposition of body by boiling HNO_3, gave ·0226 Pt and ·0061 Cr_2O_3.

9. ·1543 grm. acidified with HCl, and the Pt precipitated by H_2S, gave after ignition in air ·0446 platinum.

10. ·8408 grm. crystallised salt (dried by pressure) lost at 100° C. ·014 grm. H_2O.

The Chloride.

This compound may be obtained from the original green body, or from the dichromate, by treatment with water and lead chloride. The lead chromate is filtered off, and from the filtrate the chloride is precipitated in fine silky needles by passing in hydrochloric acid gas. The compound recrystallised from warm water is deposited in long bright green prismatic crystals, having the composition

$$(CON_2H_4)_{12}Cr_2Cl_66H_2O.$$

It is freely soluble in hot water, less readily in cold, the compound being decomposed by boiling its solution. Its aqueous solution is precipitated by potassium dichromate, the compound precipitated being similar in every respect to the dichromate just described. It also gives precipitates with platinic chloride and potassium ferrocyanide, but none with ammonia, until the compound has been destroyed by boiling or otherwise. The compound is almost completely precipitated from its aqueous solution by the addition of hydrochloric acid.

The following results were obtained on analysis :—

1. ·7943 grm. salt gave on combustion ·4036 grm. CO_2 and ·3369 grm. H_2O.

2. ·48795 grm. titrated with $\frac{N}{10}AgNO_3$ required 28·16 cub. centims.

Theory.			Analysis.									
		Percentage.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
C_{12}	144	7·01	6·92	6·66	6·89	7·23						
H_{48}	48	2·33	2·48	2·64								
Cr_2	104·8	5·10	..	..	..	..	..	..	5·04	5·24		
Pt_3	590·1	28·73	..	..	..	..	..	..	28·47	28·35	28·90	
N_{24}	336	16·31	..	..	16·23	16·29						
Cl_{18}	639	31·11	..	..	..	..	31·05	30·48				
O_{12}	192	9·41										
	2053·9	100·00										
$2H_2O$	36	1·72	..	..	..	..	..	..	..	..	..	1·66
	2089·9											

3. ·1477 grm. (another sample precipitated by HCl) titrated with $\frac{N}{10}$ $AgNO_3$ required 8·6 cub. centims.

4. ·4274 grm. ignited left ·062 grm. Cr_2O_3.

5. ·5382 grm. crystallised salt dried by pressure lost at 104° C. ·05025 grm. H_2O.

Theory.			Analysis.				
			1.	2.	3.	4.	5.
		Percentage.					
C_{12}	144	13·87	13·85				
H_{48}	48	4·62	4·70				
N_{24}........	336						
O_{12}........	192						
Cr_2	104·8	10·09	..	..	..	9·94	
Cl_6........	213	20·52	..	20·48	20·67		
	1037·8						
$6H_2O$	108	9·42	..	..	..	..	9·33
	1145·8						

The Sulphate.

This compound is readily obtained from the preceding, by the action of silver sulphate. The silver chloride is filtered off, and the solution concentrated at a gentle heat or in vacuo. If the warm solution of the chloride be rubbed up in a mortar with the proper quantity of silver sulphate, a crop of crystals of this compound is deposited after filtration, on cooling, in short dark green prisms. The crystals have the composition $(CON_2H_4)_{12}Cr_2(SO_4)_3 10H_2O$.

The following results were obtained on analysis:—

1. ·385 grm. salt, dried by pressure between bibulous paper, lost at 105° C. ·0538 grm. water, and gave, when dissolved and the sulphuric precipitated by $BaCl_2$, ·208 grm. $BaSO_4$.

Theory.		Percentage.		Analysis.
C_{12}	144			
H_{48}	48			
N_{24}	336			
O_{15}	240			
Cr_2	104·8			
$(SO_3)_3$......	240	18·56	......	18·54
$10H_2O$	180	13·92	......	13·98
	1292·8			

The Nitrate.

This compound is readily obtained from the dichromate or chloride by nitrate of silver. If the solutions used are warm and fairly concentrated, a good crop of crystals is deposited on cooling after filtration. The salt separates from the warm saturated solution, or by spontaneous evaporation in large, well-defined, dark green prisms, which are anhydrous, and may be represented by the formula $(CON_2H_4)_{12}Cr_2(NO_3)_6$. The following determinations were made:—

1. ·449 grm. crystallised salt lost no appreciable quantity of water at 104° C., and is therefore anhydrous.
2. ·0908 grm. gave 25·67 cub. centims. nitrogen at 0° and 760 millims.
3. ·378 grm. ignited left ·0493 Cr_2O_3.
4. ·22175 „ ·02895 „

Theory.			Analysis.		
			2.	3.	4.
		Percentage.			
C_{12}	144				
H_{48}	48				
N_{30}	420	35·09	35·46		
O_{30}	480				
Cr_2	104·8	8·75	..	8·94	8·95
	1196·8				

The Hydroxide.

A mixture of the dichromate, cold water, and a slight excess of pure precipitated lead hydroxide, rubbed together in a mortar, the lead chromate removed by filtration and any excess of lead by a drop of the dichromate, yields a bright green strongly alkaline solution. This solution appears to contain the hydroxide of the same base as the salts just described, for they are easily obtained from it by suitable reagents. A precisely similar solution may be obtained from the sulphate by means of barium hydroxide. The compound, however, is slowly decomposed in the cold, more rapidly on heating, the solution losing its alkalinity, chromic hydroxide separating out and urea remaining in solution. If the green aqueous solution be mixed with alcohol, most of the hydroxide is deposited as a light green precipitate, which may be collected, redissolved in water, and reprecipitated by alcohol unchanged. It is, however, difficult to prevent some decomposition occurring, especially in drying. On this account, I have not at present succeeded in isolating it in a sufficiently pure state for analysis.

Up to the present time, no compounds of chromium with ammonia have been described, which are analogous in composition to those forming the subject of this paper. The metal cobalt, however, forms with ammonia the base of Frémy's well-known series of luteocobaltic salts, to which these compounds bear a marked resemblance. Comparing the compounds at present analysed with the corresponding luteocobaltic salts:—

New Series.		Luteocobaltic Salts.
$\{(CON_2H_4)_{12}Cr_2\}(Cr_2O_7)_3 3H_2O$	....	$\{(NH_3)_{12}Co_2\}(Cr_2O_7)_3 5H_2O$
$\{(CON_2H_4)_{12}Cr_2\}(PtCl_6)_3 2H_2O$	....	$\{(NH_3)_{12}Co_2\}(PtCl_6)_3 6H_2O$
$\{(CON_2H_4)_{12}Cr_2\}Cl_6 6H_2O$	....	$\{(NH_3)_{12}Co_2\}Cl_6$
$\{(CON_2H_4)_{12}Cr_2\}(SO_4)_3 10H_2O$	....	$\{(NH_3)_{12}Co_2\}(SO_4)_3 5H_2O$
$\{(CON_2H_4)_{12}Cr_2\}(NO_3)_6$	....	$\{(NH_3)_{12}Co_2\}(NO_3)_6$

Several other compounds are in course of preparation or analysis, and will form the subject of a further communication.

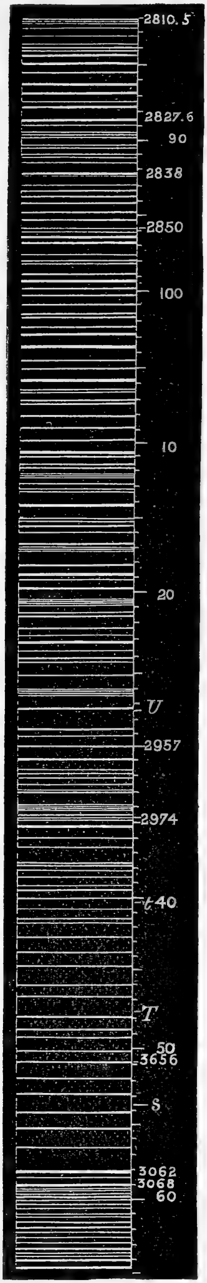
I am greatly indebted to my friend and former pupil, Mr. C. T. Heycock, B.A., for much valuable aid in the analysis of these complicated compounds.

I desire also to express my thanks to Professor Liveing for much valuable advice and assistance.

II. "On the Spectrum of Water. No. II." By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received January 14, 1882.

In our former communication on the subject of the water spectrum ("Proc. Roy. Soc.," vol. 30, p. 580) we stated that the spectrum we then figured did not by any means exhaust the spectra of flames we had observed, but it was as much as we had at that time been able to trace to water as its cause. We had, in fact, noticed in the spectrum of coal-gas and hydrogen-flames a still more refrangible but less intense series of lines; and we have since observed that this second series is produced under the same circumstances as the first, and we therefore ascribe it to the same cause, namely, the incandescent vapour of water. It is easily produced not only by the flames just mentioned, but by the arc of a De Meritens machine when a current of steam is passed into it, and by the spark of an induction coil without jar in moist air or other moist gas. When a large coil and jar are used it almost or wholly disappears.

The accompanying figure is drawn from a photograph of the spectrum of an oxyhydrogen flame; and the wave-lengths marked on


2810.5
2827.6
90
2838
2850
100
10
20
U
2957
2974
t 40
T
50
3656
S
3062
3068
60

it were derived by interpolation from the wave-lengths of the magnesium and iron lines. The arc of a De Meritens machine taken in a crucible of magnesia gave us, when a current of steam was passed into the crucible, both the water spectrum and the metallic lines on the same plate. The solar lines are marked in the figure in positions held by the corresponding iron lines. These photographs were taken with prisms of Iceland spar. None of our photographs show any more refrangible rays produced by water within the limit of transparency of Iceland spar, *i.e.*, below a wave-length of about 2200.

III. "An Attempt at a Complete Osteology of *Hypsilophodon Foxii*, a British Wealden Dinosaur." By J. W. Hulke, F.R.S. Received January 16, 1882.

(Abstract.)

The author, after giving a list of papers on remains of this Dinosaur, by Professor Owen, Professor Huxley, and himself, and noticing the great want of a complete osteology which might serve as a type, describes in detail the skull, including the dentition, the vertebral column, shoulder-girdle, and hip-girdle with the limbs, and compares their structure with that of other fossil and extant Sauropsida. He maintains the generic distinctness of *Hypsilophodon* from *Iguanodon* as typified by *I. Mantelli*, considering that the very different structure of their hind feet is decisive of this. The paper embodies the results of dissections of parts of several skeletons, and it is illustrated by figures of all the bones described.

IV. "The Influence of Stress and Strain on the Action of Physical Forces." By Herbert Tomlinson, B.A. Communicated by Professor W. Grylls Adams, M.A., F.R.S. Received January 18, 1882.

(Abstract.)

Part II.—*Electrical Conductivity.*

The temporary alteration of electrical conductivity which can be produced by longitudinal traction was measured for all the metal wires used in Part I, both in the hard-drawn and annealed condition, and, in addition, for carbon and nickel, by the following method:—The wires were suspended in pairs of equal lengths in an air-chamber 4 feet in length and 4 inches inner diameter. This vessel, which consisted of two concentric cylinders containing a layer of water

1 inch thick between them, stood upright on a stout table. The ends of the wire to be tested, and of the other wire, which will be called the comparison-wire, were clamped into three brass blocks which rested upon a support of hard wood placed on the top of the chamber. One of the blocks was twice the length of each of the other two, and into this was clamped one end of each of the wires; the other ends were clamped into the other two blocks. The blocks were provided with terminal screws, and a "Wheatstone's bridge" was formed, having four branches consisting of the wire under examination, the comparison-wire, and two sets of resistance-coils each of about 100 ohms, but capable of variation by such small amounts as ·1 ohm at a time. These resistance-coils were connected by caoutchouc-covered copper wire, several feet in length but of small resistance, to two of the brass blocks, and were also united to each other by a platino-iridium wire having a resistance of ·1 ohm, which was stretched along a scale divided into millimetres, and was traversed by a sliding-piece, which, by means of a suitable spring and catch, could be readily clamped to any part of the wire. By means of the resistance-coils and the platino-iridium wire an alteration of less than one in a million could be measured. As the change of resistance was in general very small, it was necessary to take every precaution to avoid sudden changes of temperature. It was necessary also to keep the galvanometer-circuit always closed in order to avoid errors which would otherwise have arisen from thermo-electric currents. A single Leclanché cell was employed for the current-motor, and with this it was possible in a large majority of cases to measure with the aid of a delicate reflecting galvanometer an alteration of resistance not exceeding one in a million. The wire to be strained was provided with a moveable pulley 2 inches in diameter, to which was attached by means of a stout wire passing through a small aperture in the table a scale-pan, and both wires were, before suspension in the air-chamber, surrounded with caoutchouc tubing, silk, or other insulating material.

The electrical resistances of all the substances which were examined, were, with the exception of nickel, increased by temporary longitudinal stress. With nickel, however, of which metal a wire nearly chemically pure was at length with difficulty procured,* the resistance was found to *diminish* under longitudinal stress not carried beyond a certain point; but after this point had been attained further stress began to increase the resistance. The effect on nickel appears still more remarkable when we reflect that the change of dimensions produced by the stress, namely, increase of length and diminution of section, would increase the resistance.

The *specific* resistances of all the substances, except nickel and

* Through the kindness of Messrs. Johnson, Matthey, and Co.

aluminium, were increased by temporary longitudinal stress. With aluminium and nickel the specific resistances were *diminished* by stress not carried beyond a certain limit. With nickel and carbon it was necessary to introduce slight modifications of the original method of determining the influence of stress on the resistance. With carbon, though the increase of resistance produced by a given amount of stress was greater than was the case with any of the other substances except tin and lead, this was not so with respect to the specific resistance.

In the next table will be found the mean results of the different experiments made with the various substances in the annealed condition.

Name of substance.	Increase of resistance per unit produced by a stress of 1 grm. per square centim. − signifies decrease of resistance.	Increase of resistance per unit, which would be caused by stress sufficing to double the length of the wire. − signifies decrease of resistance.	Increase per unit of specific resistance which would be caused by stress sufficing to double the length of the wire. − signifies decrease of resistance.
Iron	2111×10^{-12}	4·180	2·618
Platinum	2285	3·404	2·252
Zinc	4406	3·379	2·113
Tin	10546	2·920	1·630
Lead	17310	2·885	1·613
Silver.........	4272	3·851	1·531
Copper	2310	2·713	1·005
Carbon	9248	2·480	0·980
Platinum-silver .	2346	2·464	0·624
German-silver ..	1523	2·018	0·226
Aluminium	1896	1·276	−0·262
Nickel*........	−3216	−6·994	−8·860

The numbers given in the above table are calculated on the assumption that the alteration of resistance is proportional to the stress; this was found to be nearly, but not quite, the case. With most metals the resistance increases in a greater proportion than the stress; but with iron which has been very heavily loaded for some time, the ratio of the increase of resistance to the stress producing it after increasing to a maximum begins to diminish; and altogether, we may say, that the results here obtained completely confirm those already recorded in

* The numbers given opposite this metal are calculated from the results obtained for stresses carried up to the above-mentioned limit, and as in the case of the other substances, represent the alterations which would ensue if the changes of resistance were proportional to the stress for any amount of the latter.

Part I, which concern the temporary alterations of length produced by longitudinal traction.

One of the most remarkable features discernible in the table is the similarity of the order of the metals, as given in the last column, to that of the table of "rotational coefficients" of metals recently given by Professor Hall;* indeed, so striking is the relationship in the case of the metals iron, zinc, aluminium, and nickel, that there would appear to be no doubt that a series of experiments made with a view of determining the effects of mechanical stress and strain on the "rotational coefficients" would be of the greatest value.

Another point to be noticed is, that the alteration of the specific resistances of the alloys brass, platinum-silver, and German-silver is much less than that of the several constituents of these alloys, and at first sight there would appear to be some relation between the alteration of resistance caused by change of temperature and that due to mechanical stress; but it has been proved by these and other experiments that the increase of resistance caused by rise of temperature is in some cases one hundred times that attending the same amount of expansion by mechanical stress; and, apart from the fact that with nickel and carbon the effects of change of temperature and of longitudinal stress are of an opposite nature, it is evident that the former are to be attributed to other causes than mere expansion.

The influence of permanent extension on the temporary alteration of resistance caused by longitudinal stress was examined, and the results obtained verified the statement made in Part I that "the elasticity of a wire is diminished by permanent extension not exceeding a certain limit, but beyond this limit it is increased." The effect of permanent extension on the alteration of resistance which can temporarily be produced in nickel by traction is very remarkable.

Compression was proved to produce on the electrical resistance of carbon a contrary effect to that caused by extension; this statement applies to the alteration of specific resistance as well as of the total resistance.

Stress, applied in a direction transverse to that of the current, was also found to produce in several metals both temporary and permanent alterations of resistance of a nature opposite to those resulting from longitudinal traction. The time during which the stress was allowed to act exercised with strips of tin and zinc a large influence on the amount of the temporary alteration of resistance which was produced by the stress. In the case of the strips of tin and zinc also, the alteration of resistance seemed to be very much greater than when longitudinal stress was applied to these same metals in the form of wires.

* "Nature," November 10, 1881. Abstract of a note read by Professor E. H. Hall at the meeting of the British Association at York.

Stress applied equally in all directions by means of an hydraulic press was proved to diminish the resistance of copper and iron; and the experiments showed that the lowering of the temperature of the freezing point of water can be accurately and readily measured by observations of the change of electrical resistance of a wire. These experiments also furnished still further proof that the change of resistance of a metal wire caused by rise of temperature is due almost entirely to other causes than mere expansion.

Experiments on the permanent alterations of resistance which can be produced by stress, furnish valuable information respecting the "limit of elasticity" of metals.

There are two "critical points" in every metal at which sudden changes occur in the ratio of the permanent extension due to any load and the load itself. The first of these points fixes the position of the true limit of elasticity, and the second that of the "breaking-point." With iron there are three, and, perhaps, more "critical points."

The total resistance of most metals is permanently increased by permanent longitudinal extension, but with nickel the *total resistance* is permanently *decreased*, provided the extension does not exceed a certain limit: beyond this limit further extension causes the resistance to increase.

The rate at which a wire is "running down" under the influence of a load can be very advantageously studied by observing the permanent increase of resistance produced by the load. If P be the "breaking-load" of a metal, and p be the load actually on the wire, the decrease per unit of the velocity of the increase of resistance is inversely proportional to $P-p$: so that the breaking-load of a wire can be calculated from observations of the rate of increase of resistance when a loaded wire is "running down." The above-mentioned proportion is constant not only for one and the same metal, but for all metals.

The small effects which can be produced by permanent extension, hammering, and torsion on specific electrical resistance were very fully investigated, and are shown in the paper by a series of curves. All the metals examined, except iron and nickel, have their specific resistances increased by strain caused by the above-mentioned processes, provided the strain does not exceed a certain limit, beyond this limit further strain decreases the specific resistance. In the case of iron and nickel, on the contrary, the specific resistance is at first *decreased* and afterwards increased.

The effect on the resistance of annealed steel produced by heating and suddenly cooling was also studied, and it was proved that if the steel be heated to a temperature under "dull red," sudden cooling *decreases* the resistance; whereas if the metal be heated up to or beyond "dull red," sudden cooling *increases* the resistance: the strain, therefore, caused by this process, and that resulting from purely mechanical treatment, are similar as regards their influence on the electrical resistance.

In order to make certain small corrections rendered necessary by the changes of density of the metals after they had been subjected to extension, hammering, or torsion, these changes were very carefully measured, and were found to be in every case small.

The amount of recovery of electrical conductivity produced by time in wires, which are in a state of strain, is shown in the paper for several metals by a series of curves, and these exhibit most conclusively the superiority of platinum-silver over German-silver when an accurate copy of a standard resistance has to be kept for a long period of time; in fact, of all the metals tested, German-silver showed the most marked recovery of conductivity, and platinum-silver the least.

The recovery of electrical conductivity is in all cases attended with recovery of longitudinal elasticity and of torsional rigidity.

A full examination of the influence of permanent strain on the susceptibility to temporary change of resistance from change of temperature showed that metals may be divided into two classes. In the first of these classes, which includes iron, zinc, and platinum-silver, the strained wire is *most increased in resistance* by rise of temperature up to a certain limit of strain, whilst beyond this limit further strain diminishes the first effect. In the second class, which comprises copper, silver, platinum, and German-silver, the strained wire is *least increased in resistance* by rise of temperature, but that, here again, after a certain point of strain has been reached, the first effect begins to be diminished. It will further be shown in Part IV, that there must be some close relationship between the thermo-electrical properties of strained and unstrained metals and their susceptibility to change of resistance from change of temperature, and that strain of any kind, whether produced by purely mechanical means, such as traction, hammering, and torsion, or by the process of tempering, renders a piece of metal thermo-electrically positive or negative to a similar piece of metal unstrained, according as the strained piece is caused to be less or more increased in electrical resistance by rise of temperature.

After some trouble, means were found of measuring with considerable accuracy at 100° C. the alteration of electrical resistance due to temporary longitudinal traction, and the experiments led to the belief that the elasticity of iron and steel is not temporarily but *permanently* increased by raising the temperature to 100° C. Subsequently direct observations of the elasticity made in the manner described in Part I, but on shorter lengths of wire, placed in an air-chamber, the temperature of which could be maintained constantly at 100° C., proved beyond a doubt that if M. Wertheim, to whom we owe so much of our knowledge concerning elasticity, had examined the elasticity of iron and steel after these metals, tested at the higher temperature of 100° C., had again cooled down to the lower one, he would have found that what to him *appeared*, in the case of these metals* to be a *temporary* increase of elasticity was *really* a *permanent* one, and if the wires used had been tested several times, first at the higher and then at the lower temperature, he would have also found, *provided sufficient rest after cooling had been allowed*, that the elasticity of both iron and steel is *temporarily diminished* by raising the temperature to 100° C.

Not only is a comparatively large and permanent change produced in the elasticity of iron by merely raising the temperature to 100° C., but in the case of well annealed iron wire there is sometimes an enormous change produced in the ductility (in one specimen the ductility was diminished 50 per cent.) by the same process; and since very appreciable effects have been proved to be brought about in the same manner in the magnetic inductive capacity, the specific resistance, and the thermo-electrical properties of iron and steel, it would appear that researches on these properties might lend valuable aid in investigations on the liability of wrought-iron axles to fracture, which is produced by sudden changes of the temperature of the air.

It was further noted that shortly after the iron or steel has been heated and then cooled, there is less elasticity than when a rest of some hours has been allowed, and in fact we have in the case exactly the same kind of restitution of elasticity as we have seen takes place after a wire has received mechanical extension. With nickel the increase of elasticity produced by rest after cooling is still more remarkable.

The effects of very slight mechanical strain, and of the strain caused by raising annealed iron or steel to 100° C., and afterwards cooling, on the torsional rigidity of these metals were next examined, and it was shown that the torsional rigidity is affected in a precisely similar manner to the longitudinal elasticity, both by raising the temperature to 100° C., and then cooling, and by the strain resulting from slight mechanical traction. On the whole it was seen that as regards either purely mechanical strain, or that caused by tempering, there are for iron and steel *three* critical points: very slight strain increasing, moderate strain diminishing, and excessive strain again increasing both the torsional and longitudinal elasticity.

The temporary alteration of susceptibility to change of resistance from change of stress, which is effected in the case of nickel by raising the temperature to 100° C., is as remarkable as the susceptibility itself, and the maximum diminution of resistance which could be produced by stress when the metal was at the temperature of the room was actually *more than twice* that at 100° C.

* "Ann. de Chimie et de Phys.," 3me serie, 1844, p. 431.

The alteration of electrical conductivity which can be produced by magnetisation was carefully studied, and a full account of the modes of experimenting, of the apparatus employed, and the precautions adopted will be found in the paper. The substances examined were iron, steel, nickel, cobalt, bismuth, copper, and zinc, and in all cases, except that of copper, it was proved that longitudinal magnetisation increases the electrical resistance, whether the substance is in an annealed or unannealed condition. With copper wire no trace of change of resistance could be detected when the wire was under the influence of a powerful electro-magnetic solenoid. In the case of zinc, which was in the form of foil, no alteration of resistance was discernible until the action of the solenoid was supplemented by that of a stout iron core, which was placed inside the solenoid and round which the foil was wrapped. In the next table will be found the increase of resistance per unit produced in the different substances by an absolute electro-magnetic unit of magnetising force, when the magnetisation is longitudinal.

Name of metal.	Condition.	Diameter in millimetres.	Increase of resistance per unit produced by unit magnetising force.
Iron	Annealed	0·94	2335×10^{-8}
Steel	Annealed	0·85	1500
Steel	Unannealed	2·33	1137
Steel	Very hard......	2·33	70
Nickel	Annealed	1·05	8070
Nickel	Unannealed	7·00	4343
Cobalt	Unannealed	7·50	628
Bismuth	Unannealed	3·30	21

Of all the metals examined, annealed nickel was by far the most affected by a given amount of magnetising force.

The increase of resistance produced by magnetisation can be very accurately represented by the formula $\gamma = a \cdot \alpha + b \cdot \beta$; where γ is the increase of resistance, α the magnetising force, β the induced magnetism, and a, b constants for the same substance when the same amount of current per unit of area flows through the substance.

When different strengths of current are used in measuring the resistance of annealed iron, the alteration of resistance caused by a given magnetising force increases with the amount of current per unit of area which flows through the substance. The induction current produced by the magnetisation of the iron in a coil surrounding the latter is also greater when a current is flowing through the iron than when it is not. With annealed nickel, or with unannealed steel, there is little or no perceptible difference in either the increase of resistance or the induction current due to magnetisation, whether a current is or is not at the time flowing through the metal.

In the paper curves are shown exhibiting the connexions between increase of resistance, magnetisation, and induced magnetism. From these curves, and from the fact of the above-mentioned formula holding good, it is assumed that the resistance will go on increasing with the magnetising force even when the latter is so great that further increase of force does not produce perceptible increase of magnetism.

In some remarks made in the paper on the nature of the alteration of resistance which is produced by magnetisation, it is stated, that "had the nature of the change of resistance been the same for longitudinal mechanical stress as for longitudinal magnetisation in the case of *all* metals, there is nothing in the actual amount of alteration that might not lead us to suppose that the change of resistance from the latter cause is due to mere rotation of the molecules considered simply as molecules without regard to the electric currents, which, according to Ampère's hypothesis, are constantly circulating round these molecules. But when we find, that with nickel, longitudinal traction, which must also cause to a certain extent rotation of the molecules, but without *magnetic polarity*, actually produces decrease of resistance, we are probably right when we conjecture, that the change of resistance resulting from magnetisation is in a great measure due to the fact that the current used in the 'bridge' is encountered by a set of molecular currents circulating all more or less in the same direction, and in planes more or less at right angles to the direction of the 'bridge'-current, according as the magnetism induced is greater or less." These molecular currents would cause the current passing through the substance to flow spirally, and the effect would be aided by the action of the magnetising force itself, which action would go on increasing with increase of force, even when no appreciable further increase of induced magnetism took place. Since Professor Hall has proved that such action is possible, and that nickel, iron, and cobalt are very conspicuous in this respect, we have some support for this view.

The "circular" magnetisation which any magnetic substance undergoes when a current is conducted through it, seems to have very little or no appreciable effect on the electrical resistance of the substance, so that, if we compare the resistances of iron and platinum, the ratio of the two will be independent of the electromotor employed in the "bridge."

The effects of temporary stress on the alteration by magnetism of the resistance of an iron or nickel wire are of a somewhat similar nature to those caused by the stress on the magnetic inductive capacity of these metals, and the same may be said with regard to the effects of the permanent strains due to extension, torsion, &c. Longitudinal stress which may be made to diminish considerably the susceptibility to alteration of resistance from magnetisation, cannot even when carried to the extent of causing breakage, change the *nature* of the alteration.

There is apparently a close relationship between the "viscosity" of a metal and its specific electrical resistance, and it seems very probable that a full investigation of the former of these two physical properties by the method of torsional vibrations would afford valuable information respecting the latter.

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"On the Limit of the Liquid State." By J. B. HANNAY, F.R.S.E., &c. Communicated by Professor G. G. STOKES, LL.D., D.C.L., &c., Sec. R.S.

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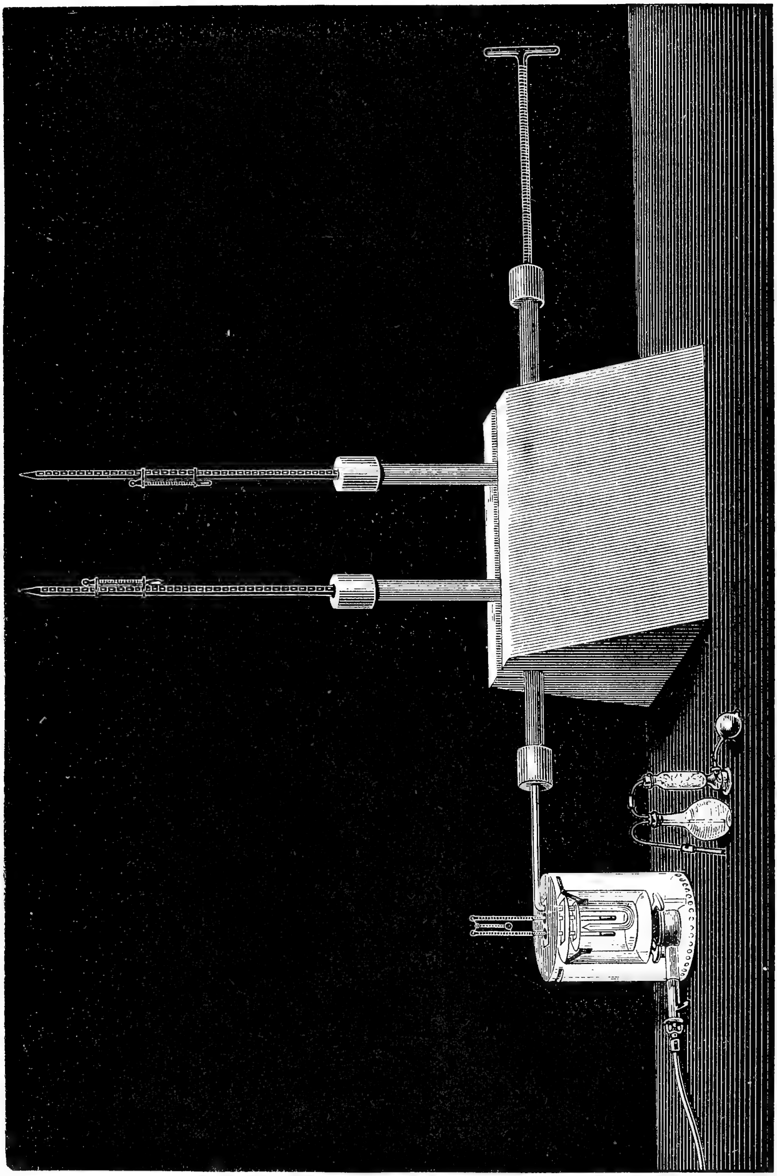
The uncertainty which characterises our knowledge of the true condition of a fluid immediately above and below the critical temperature, induced me to enter into a full examination of various fluids, with the object of gaining accurate definitions of the liquid and gaseous states, as well as to arrive at a true conception of the state of matter to which the term vapour can be applied. In a former paper, which the Royal Society has honoured me by publishing,* experiments were detailed which seemed to show that the liquid state terminated at the critical temperature, and that no amount of pressure would suffice at any higher temperature to render the fluid capable of exhibiting

* "On the State of Fluids at their Critical Temperatures." "Proc. Roy. Soc.," vol. 30, p. 484.

surface tension or capillarity; in fact, that the state of a fluid above that temperature coincided with the properties we call gaseous. The paper concluded, "The difference between the liquid and the gaseous states is not then entirely dependent upon the length of the mean free path; but also upon the mean velocity of the molecule." That is to say, we may compress a gas (when a few degrees above the critical temperature) to a less volume than it might occupy as a liquid, and it will still remain gaseous. In the following paper, therefore, the term liquid will be applied only to such bodies as exhibit surface tension. either as capillarity or by forming a permanent limiting surface when in contact with a vapour or gas. The term gas will be applied to that state of a fluid which precludes its being reduced to a liquid by pressure alone, in other words, to any fluid above its critical temperature. The term vapour will be applied, as has already been done by Andrews, to fluids which can be reduced to liquid by pressure alone, that is, to any aëriform fluid at a temperature lower than the critical. Thus carbon dioxide is a vapour at ordinary temperature, but is a gas at temperatures over 31°. A further distinction of gas and vapour lies in the fact that, on increasing the pressure, the volume of a gas goes on diminishing in a regular way, whereas there is a part of the curve representing pressure and volume of vapour where the curve is asymptotic, that is, where the vapour is in contact with its liquid.

In the following paper reasons will be shown for believing that the gaseous state depends entirely upon the mean velocity and not upon the mean free path of the molecule at all. The difference between vapour and liquid, on the other hand, is entirely one of the length of the mean free path. The methods of experiments used were similar to those detailed in the paper above referred to, but a larger apparatus was employed, so that the results might be more distinctly visible. It was soon noticed that the readings of pressures of manometers varied a little with the diameter of the tube employed, the smallest bore giving the highest reading, and this was the case to such an extent as to cause an error of two atmospheres in 70, and about five in 100; the higher the pressure the greater the difference. The wide tube was about 0·8 millim. in diameter, the smaller 0·1 millim. Now, whether this error was caused by the hydrogen condensing against the glass, and being thus lost as a manometric substance, or whether it was caused by the hydrogen being dissolved in the film of moisture which may be supposed to adhere to the interior of the tube, has not yet been determined. It has been shown by Professors Liveing and Dewar that the moisture adhering to glass is not driven off till nearly a red heat is reached, and we may be sure that the capillarity of the smaller tube would cause it to retain moisture more eagerly than the larger one. Whatever was the cause, it was almost invariably found that manometers with small bores gave higher read-

Fig. 1.



ings than those with wide bores. They were dried by passing dried hydrogen through them for over two hours and keeping them warm all the time.

In order to obtain readings which would always be near the truth, and be more independent of accidental errors, an apparatus was constructed with two manometer tubes, and the manometers were made of tubes as wide as was consistent with the strain they were destined to bear. The apparatus as used is shown in fig. 1, where the two manometers are shown fixed in the two upright branches, while the pressure screw is at the right hand, and the working tube at the left. The air-bath has been drawn as though it were transparent, to show the internal arrangement. The working tube is recurved, so that the liquid to be experimented upon is contained between the mercury and the sealed top of the tube. The air-bath consists of two cylindrical baths with holes in the lids for passing the working tube through, and an outside cover which keeps the heat from the lamp from being too quickly radiated. The internal baths are supported by one of Fletcher's solid flame burners, and the bottoms are covered by a layer of non-conducting cement. The outside cover has openings at the top for the escape of the burnt gases, and its top is covered with a thick layer of asbestos wool, to prevent cooling. The whole of the baths and cover were made of iron, as the high temperature used caused copper to scale heavily.

Two thermometers were used in the bath, one on each side of the working tube; and at first each thermometer had a little one fixed to it for temperature corrections, but it was subsequently found that one hung between the two gave quite as much accuracy.

The two thermometers used were of soda-glass with cylindrical bore, and registered the same temperatures to within 0°·5, being chosen from a number. They were heated and cooled from 270° to 0° over seventy times, and one sent to Kew, where it was compared with the standard up to 100, and the stem calibrated and the corrections up to 350 calculated. The zero points of both thermometers rose from 0°·2 to 2°·2 during the preliminary heating and cooling. The changes were determined daily. The temperatures given in this paper may, therefore, be considered practically correct.

Two small thermometers were fixed to the manometers for temperature corrections.

After trying several stands I found that shown in fig. 1 to be the most convenient and steady; it is simply a large block of wood with a groove cut in it, in which the tube lies, the two upright arms preventing any movement of the apparatus. The packing of the joints has been described before, and I would only add that I find it better to face the India-rubber packing with leather by fixing a piece of fine soft leather to the face of the plug with india-rubber solution.

This leather face is then oiled, and can be screwed up with much less damage to the india-rubber plug. The larger the screw the more easily is it kept tight. The first screw I used was $\frac{3}{16}$ of an inch, and it soon cut the leather facings; the second was $\frac{5}{16}$, and it was found to last much longer; and now working with a half-inch screw it has not required repacking for three months, although in constant use. The dimensions of the apparatus as used are as follows:—Length of horizontal tube, 24 inches; height of vertical branches, 8 inches; caps, 2 inches long by $1\frac{3}{4}$ inches diameter; screw, $\frac{1}{2}$ inch; external diameter of tube, $1\frac{1}{3}$ inches; internal diameter, $\frac{5}{8}$ inch; length of manometers, 22 inches to 26 inches; external diameter, $\frac{1}{4}$ inch to $\frac{3}{8}$ inch; internal diameter, from $\frac{1}{200}$ inch up to $\frac{1}{10}$ inch. Small bath, 5 inches high by 4 inches diameter; larger bath, 7 inches by 6 inches; external cover, 13 inches high by 9 inches diameter. In each of the baths and in the cover two vertical slits were cut and fitted with mica windows, and a light placed behind allowed an observer to see clearly what occurred. The measurements are given in English standards, as engineers who construct such apparatus always use that method of measurement.

As Amagat has shown that hydrogen is the only gas which follows Boyle's law at high pressure, that gas was always used as the manometric substance, and was carefully purified and dried before use. The drying was done by passing it through five U-tubes with pumice-stone and strong sulphuric acid, and then through two U-tubes with phosphoric anhydride. The manometers used were always 0·4 millim. in internal diameter, as narrower manometers always gave higher readings. In determining the pressure of alcohol at its critical temperature, the difference of pressure indicated by different manometers puzzled me at first, especially as there was no difference in temperature, but upon determining the diameters of the manometer tubes it was found that the highest pressures were registered by the smallest bores.

The pressure of alcohol at its critical point as registered by the different manometers was as follows:—

Temperature (theory).		Diameter in millims.		Pressure in atmospheres.
232°·14	....	0·142	....	69·7
232·07	....	0·272	....	69·1
232·12	....	A 0·480	....	68·1
231·99	....	B 0·628	....	67·9

These numbers are the means of thirty measurements in each case. The manometers A and B were used in most of the first portion of the work, but as they both broke subsequently, they were replaced by two others, A′ and B′, and these again by A″ and B″. When a pressure of over 300 atmospheres is required, these wide manometers are very apt to burst, so that for high pressures a narrower tube must be used.

The first work undertaken was to ascertain without doubt the critical point of pure anhydrous ethyl alcohol, and this was done as follows:—The alcohol sold as absolute by the makers was fractionated, and the middle third taken. This was placed in a retort with freshly burnt lime, and an inverted condenser adapted to it. After it had been boiling for some time, the end of the condenser was fitted with a drying tube of calcium chloride, to prevent moisture from entering. The cohobation was continued for a week, and the alcohol then distilled off. The first fifth was rejected, as was also the last. The receiver was a small flat-bottomed flask, which is shown fitted up for use (after it was filled with alcohol) in the front of the drawing. It was arranged as a wash-bottle, having the tube for the entrance of air connected with a small vitriol tower, and an india-rubber ball, fitted with valves, to apply pressure. The exit tube was adapted to the experimental tube by a piece of india-rubber tubing, through which was forced a piece of capillary tubing. When the apparatus was to be used in experiment the arrangements were made as follows:—The cap with the pressure-screw was first fitted on next the experimental tube, with its point sealed up, and the whole filled up to the top of the manometer branches with mercury. The manometers were now placed in position and screwed tight. The apparatus was then tilted so as to raise the point of the experimental tube, keeping it, however, above the level of the lower ends of the manometers, and the point then broken off. If the point were below the level of the manometers some gas might escape. The wash-bottle arrangement is then fitted to the experimental tube and the ball compressed. Alcohol is driven over and escapes by the capillary tube, and this is continued till the inside of the tube has been well washed and all impurities removed. The capillary tube is then withdrawn, when the small puncture in the india-rubber at once closes itself. The screw of the pressure apparatus is then retreated, and when sufficient alcohol is made to enter the apparatus, the joint is undone and the whole wash-bottle arrangement placed under a bell-jar over oil of vitriol for use another time, the india-rubber tube being clipped. The screw is then further retreated to leave a small air-space over the alcohol, which is then boiled and the point sealed, and the tube placed in the air-bath. A mercury regulator, such as I have described elsewhere, was sometimes used when the temperature was required to be constant for long.

The following tables contain some of the series of observations on alcohol, and are given to show the numbers obtained when the work is done with every care. The alcohol used was different in each case, so that slight variations in the averages may be due to differences in the liquid used. The numbers for pressures are arbitrary scale readings, and are reduced to actual pressures at the end of the tables.

Table No. I.

Critical Temperatures and Pressures of Alcohol.

T and T′ are the two thermometers in the bath, one on each side of the experimental tube.
t and *t*′ two thermometers for correction of T and T′.
P and P′ are the readings of the two manometers A and B.
t″ and *t*‴ two thermometers for correction of manometers.

T.	T′.	*t*.	*t*′.		P.	P′.	*t*″.	*t*‴.
233	234	72	84	......	187 ·2	224 ·5	16 ·5	17
232	233	75	89	......	187 ·8	224 ·7	17	16 ·8
232	234	74	85	......	185 ·9	223 ·4	18	17 ·5
235	235	75	80	......	188 ·5	225	17	16 ·9
230	230	82	75	......	185 ·9	223 ·3	18	18 ·2
232 ·5	235 ·5	90	85	......	192 ·4	225 ·7	15	15
233	234 ·5	88	92	......	191 ·6	225 ·5	15	15 ·5
232	230 ·5	85	87	......	186 ·2	224 ·3	15	15
232	230	90	85	......	187 ·3	224 ·7	16	16
232	230	92	85	......	187 ·8	224 ·8	16 ·5	16 ·2
231	234	85	67	......	187 ·8	224 ·7	16 ·2	16 ·5
235	234 ·5	69	85	......	181 ·5	223 ·5	17 ·5	17
234	234	92	72	......	187 ·2	224 ·5	17 ·3	17
232 ·5	232 ·5	90	84	......	188 ·5	224 ·8	18 ·2	18
236	237	86	90	......	188	224 ·7	16 ·5	16 ·2
233	232	80	84	......	186 ·9	224	15 ·5	15 ·3
235	236	92	78	......	187 ·2	224 ·5	14 ·5	15
231	232	84	90	......	185 ·2	224 ·1	15 ·5	15 ·8
230	231	82	84	......	193 ·6	225 ·9	16 ·8	16 ·5
230 ·5	232	94	82	......	184	225 ·8	16 ·2	16
230 ·8	229 ·5	85	80	......	187	224 ·5	16	16
231 ·5	234	82	85	......	186 ·1	224 ·3	15	15
233 ·5	232 ·5	90	87	......	185 ·4	224 ·2	17	16 ·8
234	234	90	89	......	196 ·7	226 ·5	17 ·3	17 ·2
233	230	85	85	......	196 ·3	226 ·4	16 ·8	16 ·6
233	234	62	72	......	189 ·4	225	20 ·5	20
233	232	65	60	......	189 ·6	225	18 ·7	19
232	231	86	68	......	188 ·5	224 ·8	19 ·2	19
229	231	72	65	......	186 ·8	224 ·4	18 ·5	18 ·5
230	231 ·5	60	65	......	186 ·6	224 ·4	17 ·5	17
229	230 ·5	68	65	......	186	224 ·2	16	16
231	230	69	69	......	187 ·2	224 ·5	15 ·5	15

T.	T'.	t.	t'.		P.	P'.	t''.	t'''.
233	231	75	74	......	181·5	223·5	14·9	15·5
231	230	72	73	......	181·7	223·6	16·2	17·2
230	231·5	79	84	......	185·2	224·3	15	15·5
229	229	92	80	......	184·8	224·2	16·2	17·2
230	230·5	87	85	......	187·8	224·8	18·5	16·7
231	231	75	82	......	187·7	225	17·2	18·5
231·5	231·5	85	90	......	185·2	224·8	19	16
232	232·5	80	80	......	182·7	224·2	15	15·9

Portion of thermometer scale exposed, 80° to 232°.

Average T 231°·97 }
" T' 232°·21 } Corrected average 235°·67.

Height of mercury in manometer above tube P = 0·91 atmos.
" " " " P' = 1·14 "

Average P 187·36 }
" P' 224·82 } pressure in atmos. Corrected { 67·14 / 67·98 } 67·56 atmos.

Probable error of mean temperature 0°·19.
" " pressure 0·13.

Table II.

Critical Point of Alcohol continued.

Manometers A' and B'.

T.	T'.	t.	t'.		P.	P'.	t''.	t'''.
231·5	232	82	78	......	288	143	19	18·5
232	231	80	82	......	287	140	20	19·5
233	233	78	75	......	289	145	19	20
233·2	233·5	79	76	......	288	144	20	20
233	233	80	85	......	287	140	21	21
232	232·5	81	79	......	290	148	20	20
233	233	82	81	......	287	140	20	19
231	229	79	84	......	290	147	19	18·5
231	229	80	72	......	288	143	16	17
231	229	79	78	......	287	140	16	16·5
230	230	78	85	......	287	140	17·5	16
231·5	231	82	92	......	286·5	140	17	17
231	231·5	81	88	......	287	140·5	16·5	16·5
231·5	232	85	77	......	288	144	15	15·5
231·7	231·7	84	80	......	287	141	16	16
232	232·5	75	81	......	289	143	17	16·5
232	232	78	78	......	290	148	18·5	18
232·2	232	79	79	......	290	149	18·5	18

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
231·8	231·5	80	85	......	288	147	18	18
231·8	232	82	79	......	287	142	17	17
231·5	232·2	81	80	......	288	144	16	16
232·2	232·2	80	80	......	288·5	145	16·5	16
232	232	80	81	......	287	142	16·5	17
232·2	232·5	81	80	......	287	140	17	17
232	232	85	81	......	285	138	16·5	18
232·2	232·2	76	80	......	287	142	15·5	16
232	232	77	78	......	285	138	15	15
231·8	232·2	75	76	......	288	145	14·5	14·5
232	232	80	79	......	287	142	15·5	15
232	232	78	80	......	287	143	15	15

Portion of thermometer exposed, 82° to 232°.

Average of T 231°·87 } Corrected mean temperature, 235°·43.
„ T′ 231°·85 }

Height of mercury in manometer above experimental tube—

Average P 287·66 } Corrected mean pressure { 66·90 } 66·88.
„ P′ 142·17 } { 66·86 }

Probable error of mean temperature 0°·16.
„ „ pressure 0·09.

Table III.

Critical Temperature and Pressure of Alcohol.

Manometers A″ and B″.

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
232	232·5	82	78	......	212	122·8	16	18
230	232	75	82	......	212·5	123·5	17	17
232	232·2	78	78	......	213	125	19	18
232·2	232·5	80	80	......	211	121	20	19
232·2	232·5	82	81	......	210·5	120	20·5	20·5
232	232·5	84	83	......	211	121	20	20
233	232	80	80	......	211·5	122	19	19
232	232·2	80	79	......	212	123	18·5	18
231·5	232·8	80	76	......	212·2	123·4	18·5	17
232	231·5	80	81	......	212·1	123·2	18·6	19
232·5	232	85	83	......	211·9	123	19	19
231·5	231·8	82	82	......	212	121	18	17
232·5	231·5	89	87	......	212·3	123·7	17·5	16
232	232	72	75	......	211·6	121·8	16·5	16·5
231·5	232·5	74	75	......	212·2	122·7	14·2	14

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
234	232 ·5	70	76	......	212 ·5	124	14 ·5	15
232	232	78	77	......	213	125	16	16 ·5
231	231	79	79	......	211	120 ·5	16	16
230	229	77	80	......	210 ·5	120	15 ·5	15 ·5
231·5	230·5	75	80	......	211 ·8	121	15 ·5	16
232 ·5	232	82	80	......	211 ·7	121	15 ·5	16
233	231	83	82	......	211 ·3	123	16	15
232	231 ·5	84	83	......	212 ·1	123	16	16
232	231 ·8	81	80	......	212 ·0	122 ·8	16	16
232 ·5	232	85	86	......	212 ·2	123	15 ·5	16 ·5
233	232 ·5	80	80	......	211 ·8	122	15 ·5	15 ·5
231	231 ·5	80	81	......	212 ·5	122 ·9	17	17 ·5
231 ·5	231	79	78	......	212 ·6	123 ·5	19	18
229 ·5	230 ·5	75	80	......	212 ·2	123	15 ·5	15
231 ·5	232	78	80	......	211	121	15	15
232	231	75	74	......	212 ·2	122 ·8	16	15
232 ·5	232 ·5	78	78	......	212 ·5	123 ·9	18	17

Portion of thermometer exposed, 80° to 232°.

Average T 231°·88 }
,, T′ 231°·77 } Corrected mean temperature 235°·39.

Height of mercury in manometers over experimental tube—

Average P 211·92 }
,, P′ 122·48 } Corrected mean pressure { 66·75, 66·82 } 66·78 atmos.

Probable error of mean temperature 0°·10.
,, ,, pressure 0·06.

We see from the foregoing tables that the mean of over a hundred experiments gives a critical point for alcohol of 235°·47 under a pressure of 67·07 atmospheres. The reason why so many experiments were done was because the first two or three series did not agree well, and it was only after some experience was gained at the work that good results were obtained. I have no doubt that by further refining of the methods better results would be obtained, but I do not think the above numbers would require material alteration. Having now fixed the critical temperature and pressure of alcohol under its own vapour, the next work consisted in determining the critical temperature of the same liquid under greater pressure. When any greater pressure than the critical is used, the tube is filled with a homogeneous fluid, the two states of a fluid being impossible under such a pressure. The critical state cannot, therefore, be observed under such conditions, as all the phenomena by which the liquid state can be recognised are dependent upon the observation of a limiting surface having a certain contractile power, and such power cannot be observed except the liquid have a free surface—that is, a surface bounded by another fluid with which it is not miscible. It was found that all liquids such as water, hydrocarbons, ethers, &c., however immiscible they may be at ordinary temperatures, mix freely or act upon one another long before the critical point of one of them is reached; therefore liquids will not serve to furnish a free surface. A gas, therefore, is the only substance which will bear any pressure without becoming miscible; and if it is insoluble in the liquid (and all liquids have some gases insoluble in them) we are provided with a substance to overlie the liquid which will allow of a limiting surface being seen at any pressure. This was the method used. A quantity of pure dry hydrogen was placed over the alcohol, and pressure applied, and the effect of rise of temperature observed. It was seen that when the temperature rose to the critical point the line dividing the alcohol from the mixture of alcohol vapour and hydrogen became quickly indistinct, and was replaced by a broad mark, indicating a gradual change in the refractive index of the fluid when passing the place where the liquid surface had been, showing that diffusion was taking place. On lowering the temperature before much diffusion had taken place, the point where the liquid surface had been became dim just as the temperature passed below the critical temperature and the sharp limiting surface became re-established.

The pressure was then increased by decreasing the volume of hydrogen, and the experiment repeated many times at the new pressure. The temperature must be raised much more slowly for these observations than for the simple observation of the critical point with alcohol alone, as in the latter case the upper and lower portions of the fluid become of the same density, instantly obliterating the line of the meniscus; but when hydrogen is above the alcohol the line remains although the alcohol be gaseous, until it is obliterated or broadened by diffusion. Thus, on raising such a mixture to the critical temperature, it is necessary to keep the temperature steady, to ascertain whether or not diffusion will take place. If a rise of temperature is going on, the thermometers will register a higher temperature than that at which diffusion began. In this way the following series of observations were carried out:—

Table IV.

Alcohol with Hydrogen.

Manometers A″ and C.

T.	T′.	t.	t'.		P.	P′.	t''.	t'''.
230	232	80	75	......	220	288	17	17
229	229	75	73	......	221·5	291	20	18
231	230·5	78	70	......	219	287	21	19

T.	T′.	*t*.	*t*′.		P.	P′.	*t*″.	*t*‴.
234·5	229·5	77	72	......	219	287	18	16
234	228·5	76	80	......	219·5	287	19	15
232	231	73	82	......	219·5	287	17	15
233	232·5	82	80	......	217	285·5	16	16
232	232·5	78	80	......	220·5	288	15	15
232·2	232·5	79	74	......	219·8	287	14	14
231·5	232·5	62	74	......	215·5	282·5	15·5	15
231·5	232·5	69	69	......	218·8	286	16	16
233	232	74	74	......	220	287·5	17	17
231·5	232·2	72	73	......	219·5	288	16	15
232	231·5	79	79	......	217·5	286	17	17
232	233·5	85	82	......	217·5	285·5	15·5	16
233·5	232·5	87	85	......	212	275	16	16
232	233	82	83	......	219	285	17	18
232·5	232	80	78	......	218	284	17	17
231	231·5	76	76	......	219·5	287	15	15
231·5	232·5	76	74	......	219·8	287	16	15
232	233	75	80	......	221·1	288·2	17	17
231·5	232·5	75	78	......	223	283	19	18
229	228·5	79	80	......	218·8	286·5	17	17
229·5	229·5	80	80	......	218·9	285·5	16	16
230	229	80	80	......	219·2	287	16	16
231	232	77	78	......	218·6	286·3	16	16
231	231	78	80	......	218·5	286·2	17	17
230	230	79	79	......	219·2	286·9	15·5	15·5
229	230	76	77	......	219·3	287	18	17
230	229	84	82	......	218·8	286·5	17	17
228	228	80	80	......	218·7	286·5	17	16
230	220	80	79	......	218·8	286·6	16	16

Portion of thermometer scale exposed 82° to 232°.

Average T 231°·30 }
" T′ 231°·16 } Corrected mean 234°·78.

Height of mercury in manometers over tube { P = 0·93 atmos.
{ P′ = 0·87 "

Average P 218·89 }
" P′ 286 45 } pressure in atmos. Corrected { 82·44 / 82·63 } 82·53 atmos.

Probable error of mean temperature 0°·17.
" " pressure 0·08.

From this it would appear that the critical temperature, or, at least, that temperature at which the meniscus disappears, is lowered slightly by the hydrogen gas. Further experiments were conducted to settle this point.

Table V.

Alcohol with Hydrogen, Thermometer D.

T.	T′.	t.	t′.		P.	t.
234	228	78	77	......	290	15
232	230	82	80	......	291	16
232	232	75	73	......	290	18
231 ·5	231	80	79	......	291	16
229	231 ·5	82	84	......	291	17
230	231	77	78	......	292	18
231	232	72	75	......	288	17
232	231	79	78	......	290	15 ·5
230	230	81	81	......	289	16
231	231	82	82	......	288	15 ·5
231	231	80	79	......	288	17
229	229	75	75	......	292	16
228 ·5	228	80	82	......	291	17

Average T 230°·26 } Corrected mean 234°·14
„ T′ 230°·84 }

Average P 290·07. Corrected pressure 183·7 atmos.

Probable error of mean temperature 0°·34.
„ „ pressure 0·19.

Table VI.

Alcohol and Hydrogen.

Manometers A″ and B″.

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
232	231	68	72	......	222	171	15	15
231 ·5	232	72	72	......	222 ·4	170 ·2	16	16
232 ·5	233	84	80	......	223	172	17	17
233	232 ·5	92	90	......	222	171	16	16
231	231	92	92	......	221 ·8	169 ·5	18	18
229	230	90	90	......	222	171	17 ·5	17 ·5
234	235	88	90	......	222 ·2	171 ·2	15 ·5	15 ·5
231	232	75	74	......	223	171 ·4	16	16

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
230·5	230·5	75	78	......	222·2	170·3	15	15·5
231	232	78	78	......	222·2	170·2	15	15
232	232	82	80	......	222·4	170·2	16·5	16
232	232·5	82	82	......	222	170·5	17	17
232	232·5	80	80	......	222·2	170	18	18·5
233	233·5	77	77	......	221·5	170·2	18·5	18·5
232	232	78	78	......	221·8	169·4	19	19
231·5	231	76	76	......	221·9	169·8	16	17
231·5	231·5	72	74	......	223	170	16	16
232	231·5	82	80	......	222·5	171·3	15	15·5
231	231	80	79	......	222·7	170·6	16·5	16
232	232	75	75	......	222·8	170·9	17	17
233	234	76	78	......	222·4	171	16	16
233·5	234	75	76	......	222·8	170·5	16	16
232·5	232·5	74	73	......	222·8	171	15	15
232	232	77	77	......	222·6	171	15	16
232	232	72	72	......	223	170·8	16	15
232	232	78	78	......	222·4	171·8	15·5	15
232	232·5	78	79	......	222·2	170·7	15·5	15
232·2	232·7	79	80	......	222	170	17	17
232·8	232·2	78	80	......	222·4	169·8	16·5	17
231·5	232	77	78	......	222·8	170·5	17	17
231·7	231·5	77	75	......	222·4	170·9	16	17
231·5	231	80	79	......	222·5	170·4	15·5	16
232	232	81	82	......	223	170·6	15	15
233	233	80	80	......	223·1	170·8	16·5	15·5
233·5	233·5	79	79	......	223	171·9	17	16
231	231·5	78	78	......	222·4	171·7	18	17·5
230·5	230·5	80	81	......	222·2	170·5	18	18
230·5	231	81	80	......	222	170·2	17	17
232	232	85	85	......	222·7	170·8	18	17·5
232·5	233	80	80	......	222·5	170·5	17	17
232	231·5	75	78	......	222·6	171·3	16	17
234	233	79	78	......	222·8	171·5	18	18
231·5	232	80	78	......	222·4	172	17·5	17

Average T 232°·16 }
,, T′ 232°·09 } Corrected mean 235°·68

Average P 222·44 }
,, P′ 170·74 } Corrected mean 122·72 atmos.

Probable error of mean temperature 0°·09.
,, ,, pressure 0·10.

Table VII.

Alcohol with Hydrogen.

T.	T′.	t.	t′.		P.	P′.	t″.	t‴.
230	231	75	76	......	226	191	16	16
230·5	231	80	82	......	227	192	17	17
231·5	232	82	80	......	226·6	191·4	15	15
232	232	92	90	......	226·4	191·6	15	15
233	231	85	85	......	226·4	191·2	15	15
232·5	233	90	92	......	226·5	191	15	15·5
232	231	82	80	......	226·2	192·2	15·5	16
229	230·5	78	77	......	227	191·8	16	16
230·5	230	76	76	......	226·8	192	16	16·5
231·5	231·5	77	77	......	227	191·4	15·5	15·5
232	230	82	82	......	226·2	191	16	16
231·8	232	80	82	......	226	191·2	17	17
230·4	232	73	72	......	226·4	191·4	18	17·5
232·5	231·3	72	75	......	226·6	191·3	17	17
231	232	80	80	......	226·9	192·1	15	15

Average T 231°·35
" T′ 231°·61 } Corrected mean 235°·04.

Average P 226·58
" P′ 191·55 } Corrected mean 178·80 atmos.

Probable error of mean temperature 0°·18.
" " pressure 0·07.

From these tables we see clearly that the critical temperature is not materially altered by a very large increase of pressure; in fact, in the last case the pressure is nearly three times as great, and yet we have only a lowering of the critical temperature by about one degree. It was found, however, that as the pressure was increased the solubility of the hydrogen in the alcohol also increased, so that at high pressures a very considerable lowering of the critical temperature takes place. When the two fluids have thoroughly mixed at a temperature over the critical point, the passage of the mixture through the critical temperature downwards is not attended with immediate liquefaction; in fact, this does not take place till a temperature 10° lower is reached, the hydrogen preventing the alcohol from assuming the liquid condition. At a pressure of 250 atmospheres the meniscus disappeared, or rather became broad at 225°; but diffusion did not take place completely; the surface seemed to be destroyed, but the action did not go deeper, while at 300 atmospheres the meniscus was lost at 220°. This is plainly owing to the action of the compressed hydrogen, and could we have a gas quite insoluble in the liquid, this lowering would not take place. It seems clear then that the temperature at which the permanent surface of a fluid (which constitutes liquidness) disappears is not altered by increase of pressure, and this is equivalent to saying that the critical point is the termination of an isothermal line which marks the limit of the liquid state.

It next remained to be seen whether any other insoluble gas would act in the same manner as hydrogen. It must be remembered that hydrogen is furthest removed from the liquid condition and the least dense body known, and the nearer the density of the superincumbent gas approaches to the density of the liquid, the greater effect will it have upon the critical temperature. To test this, a quantity of nitrogen was placed over alcohol, and the experiment conducted similarly to those with hydrogen.

Table VIII.

Alcohol with Nitrogen.

Manometer C.

T.	T′.	t.	t′.		P.	t″.
231·5	232	78	79	......	274	16
232	231·5	77	77	......	267	16
231·5	231·5	78	78	......	262	15·5
232·5	232	80	81	......	262	15
232	231·5	82	80	......	270	15
231·5	232	80	80	......	270	15
232·5	232	81	81	......	276	16
230	231	80	82	......	276	17
229	230	80	78	......	276	18
231·5	232	75	74	......	278	17
231·5	231·5	76	78	......	277	16
232·5	232	78	80	......	273	15

Average T 231°·50 }
,, T′ 231°·58 } Corrected mean temperature 235°·11.

Average P 271·75. Corrected mean pressure 82·35 atmos.

Probable error of mean temperature 0°·22.
,, ,, pressure 0·19.

These numbers plainly show that the meniscus of alcohol disappears at the same temperature, whether under the pressure of its own vapour or at a pressure of eighty atmospheres with nitrogen, affording further proof that the liquid state terminates at the critical temperature.

Another method still remained to be tried, that of measuring the capillary height of a liquid under various pressures and temperatures. The method used at first was to fix a small piece of capillary tubing into the interior of the working tube by melting a small piece of silicate of soda, and causing the tube to adhere; but this was found to be disadvantageous, as the tube almost invariably burst where the silicate was adhering. The method latterly used was simply to make an obtuse-angled bend on the tube, so that the piece of capillary tube could not pass beyond this, but became wedged. The capillary height was measured by a cathetometer in the usual manner.

The following table gives the results:—

Table IX.

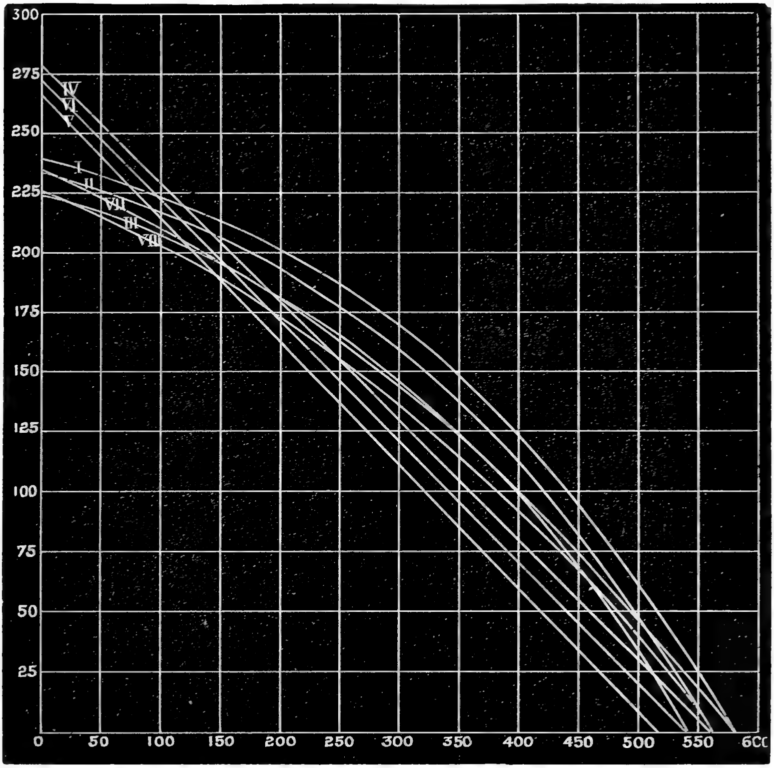
Capillary Height of Alcohol.

Manometers A″ and B″.

T.	T′.	*t*.	*t*′.		P.	P′.	*t*″.	*t*‴.		Cap. Ht.
10·5	10·5	..	..	....	..	..	..	..	....	564
19	19	16	16	....	..	..	..	..	....	557
34	34	16	15·5	....	..	..	..	..	....	540
54	53·8	15·5	15·5	....	..	..	..	..	....	513
67	67	15	15	....	..	..	..	..	....	487
81	80·5	16	16	....	..	..	..	..	....	468
90	90·2	17	17	....	..	..	..	..	....	450
108	108	16	16	....	..	..	..	..	....	428
122	122	18	17	....	..	..	..	..	....	402
127	127	18	18	....	..	..	..	..	....	388
137	136·5	20·5	20	....	..	..			....	374
145	145	23	23	....	80	..	16		....	358
155	154·2	27	27	....	92	..	16		....	334
166·5	166·5	35	34	....	112	..	16·5		....	300
172	173	42	40	....	137·5	..	17		....	264
186	186	53	50	....	165	..	17		....	238
192	193	60	60	....	185	..	16·5		....	211
195	195	60	61	....	189·5	27	16·5		....	194
202	202	65	66	....	199	52	16·5		....	179
205	205·5	70	72	....	204	83	16		....	161
209	210	70	70	....	206	90	15·5		....	141
214	214	72	75	....	208·5	107	15		....	127
220	220·5	75	75	....	210	115	17		....	84
225	224·5	78	78	....	211	118·5	17		....	49
229	230·5	79	80	....	212	123	17		....	8

From this table curves Nos. I, fig. 2, and IX, fig. 3, have been drawn, while Table X gives the corrected values for capillary height under the pressure of alcohol vapour. The numbers expressing the pressure of the vapour at temperatures below those at which the manometers used began to register are taken from Regnault's observations.

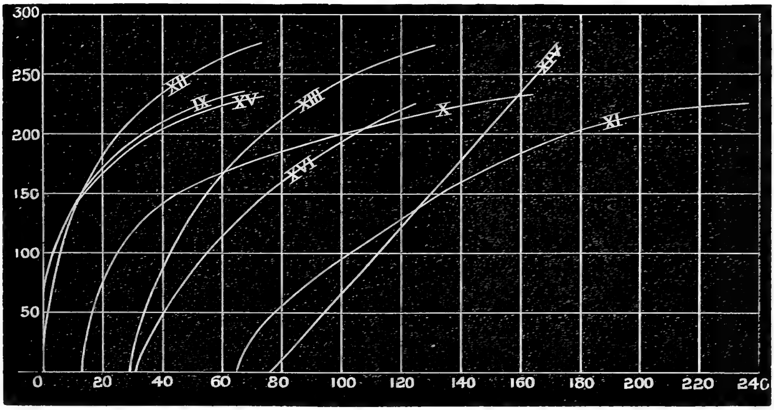
Fig. 2.



T°.

Cap. Ht.

Fig. 3.



T°.

P.

Table X.

Curves I, Fig. 2, and IX, Fig. 3.

T.	P. in atmos.	Cap. Ht.
235 ·4	66 ·7	0
230	64 ·9	40
220	58 ·7	99
200	37 ·5	198
180	18 ·1	269
160	10 ·9	321
140	7 ·4	365
	millims.	
120	3219	401
100	1694	436
80	812	467
60	350	501
40	134	530
20	44	555
0	13	579

As examples have now been given of the numbers obtained in all the different methods employed, and the probable error calculated, the tables of original numbers will be omitted and only the corrected values given, and where several observations have been made the probable error will be given.

The following table gives the capillary heights of alcohol at various temperatures under compressed hydrogen, giving a much higher pressure than the vapour alone.

Table XI.

Curves II, Fig. 2, and X, Fig. 3.

Alcohol Capillarity under Pressure.

T.	P in atmos.	Cap. Ht.
230 ·3	163 ·5	0
220	125 ·0	63
200	106 ·0	159
180	79 ·0	234
160	53 ·5	286
140	37 ·0	333
120	27 ·8	372
100	24 ·3	409
80	22 ·1	442
60	18 ·3	473
40	16 ·7	503
20	15 ·0	531
0	14 ·2	557

Table XII.

Curves III, Fig. 2, and XI, Fig. 3.

Capillary Height of Alcohol under High Pressure.

T.	P in atmos.	Cap. Ht.
224·6	236·8	0
220	224·9	26
200	182·2	129
180	145·3	207
160	136	264
140	128·1	312
120	114	354
100	100·1	391
80	86·8	428
60	79	458
40	69·1	489
20	66	517
0	64·2	544

From these tables we see that the capillary height of the liquid is lowered by a gas under pressure impinging on its surface. Thus at 66·7 atmospheres (the critical pressure of alcohol), the capillary height falls to zero at 235°·4, at 163·5 atmospheres of pressure zero is reached at 230°·3; while at 236·8 atmospheres capillarity disappears at 224°·6. It is curious to note that, although the capillary action had ceased at these temperatures, the liquids had not assumed the gaseous state, as Tables IV, V, VI, VII, and VIII show that in no case up to a pressure of 183 atmospheres did the alcohol diffuse into the hydrogen at a temperature below 234°.

As capillarity is entirely a surface phenomenon, the surface tension of a liquid seems to be weakened by the impinging of a gas under pressure upon its surface, and this we might expect to be the case, as we can imagine a constant disturbance of the surface of the liquid, owing to the high velocity of the hydrogen molecules striking it; whereas, not being soluble to any extent, few hydrogen molecules penetrate to disturb the liquidness of the interior. It would thus appear that, under such conditions, capillarity is not a true measure of the liquidness or cohesion of a fluid, and were the pressure high enough the surface of a liquid might be made to disappear, while its interior was in a truly liquid condition. This question can be most readily settled by passing a liquid, whose surface tension has thus been caused to disappear, through a capillary tube, and observing whether increase of temperature diminishes the time of flow, for the resistance of a fluid is decreased by increase of temperature, while that of a gas is increased. The experimental realisation of such a test is difficult, but apparatus is being at present constructed for the trial.

In drawing out the above tables (which may exhibit slight irregularities) recourse was made to a large number of quite separate observations, as full series are often difficult to obtain, owing to some failure in the apparatus when it has been in use for some time at high pressures.

Hitherto only one liquid—alcohol—had been used in these experiments, so it was determined to try the same experiments with other liquids, and those chosen were carbon disulphide, carbon tetrachloride, and methyl alcohol.

The carbon disulphide was digested over sodium for some time and distilled off pure quick-lime. This gives a liquid having no offensive odour and quite colourless. It was distilled into an apparatus similar to that used for alcohol, and preserved under a bell-jar over oil of vitriol. Four sets of observations were done in order to determine the critical temperature and pressure accurately; in all 163 experiments. The results are as follows:—

Mean temperature corrected......	277°·68.
Probable error of mean........	0°·16.
Mean pressure corrected	78·14 atmos.
Probable error	0·07 ,,

The apparatus was now arranged so that the critical temperature could be observed under pressure with hydrogen with the following results:—

Mean temperature corrected......	274°·93.
Probable error	0°·09.
Mean pressure corrected	171·54 atmos.
Probable error	0·07 ,,

For these numbers sixty-two experiments were done.

Nitrogen was then substituted for the hydrogen, and the experiments conducted as before. Forty-one determinations were made to obtain the following means:—

Mean temperature corrected......	273°·12.
Probable error	0°·19.
Mean pressure corrected	141·45 atmos.
Probable error................	0·16 ,,

Here we see that while the pressure of the nitrogen on the carbon disulphide is much lower, the temperature at which the meniscus disappears is also lower. This is likely owing to the greater solubility of the nitrogen in the liquid, as the density makes it approach much nearer to the density of the disulphide than hydrogen.

A third series was conducted with hydrogen, using, however, a much lower pressure:—

Mean temperature corrected......	277°·55.
Probable error	0°·14.
Mean pressure corrected	95·86 atmos.
Probable error	0·09 ,,

Here we see only a very faint lowering of the critical point, only 0·2 of a degree, although the pressure has been increased twenty atmospheres. The capillary height of the disulphide under various conditions was next determined. The numbers gave as follows:—

Table XIII.

Curves IV, Fig. 2, and XII, Fig. 3.

Capillarity of Carbon Disulphide.

T.	P in atmos.	Cap. Ht.
277	78·1	0
260	58·1	45
240	43·8	74
220	33·7	114
200	25·5	155
180	19·6	197
160	14·8	236
140	10·9	277
120	7·6	316
100	4·3	359
80	2·8	397
60	1·6	437
40	0·8	476
20	—	517
0	—	558

Table XIV.

Curves V, Fig. 2, and XIV, Fig. 3.

Capillarity of Carbon Disulphide with Hydrogen.

T.	P in atmos.	Cap. Ht.
260	172·1	0
260	167·2	9
240	160	46
220	153·5	84
200	146·3	122
180	138·2	164

T.	P in atmos.	Cap. Ht.
160	131 ·5	203
140	124 ·8	242
120	117 ·7	278
100	110 ·9	317
80	103 ·8	358
60	96 ·5	394
40	90 ·2	434
20	83 ·2	473
0	78	515

Table XV.

Curves VI, Fig. 2, and XIII, Fig. 3.

Carbon Disulphide with Nitrogen.

T.	P in atmos.	Cap. Ht.
273	131	0
260	112 ·5	23
240	96 ·1	61
220	83 ·8	100
200	73 ·2	141
180	64 ·3	197
160	58 ·1	236
140	52 ·2	278
120	46 ·8	317
100	42 ·7	358
80	39 ·2	395
60	37 ·7	436
40	33 ·3	478
20	30 ·4	517
0	28 ·1	555

On examining these tables, and the curves which graphically represent them, we see that here also the capillary action of the liquid is weakened by a gas impinging upon its surface, even at low temperatures, and again we see that the capillarity is reduced to zero before the liquid is really gaseous, showing that like alcohol the surface tension of carbon disulphide is destroyed by the activity of the molecules of the gas overlying it. The curve for carbon disulphide and hydrogen, XIV, fig. 3, should not be really a straight line, but a number of accidents happened during these experiments, and the curve is made up from many readings from different manometers, that for the middle part of the curve evidently reading a little low. The whole result agrees well with what was shown from alcohol.

The next body examined was methyl alcohol, a sample of which was carefully purified in the same manner as the ethyl alcohol, until its boiling point was constant. It was then distilled off quick-lime into the wash-bottle arrangement for use. It gave as follows :—

Mean temperature corrected......	232°·76.
Probable error................	0°·21.
Mean pressure corrected	72·85 atmos.
Probable error	0·12 „

These means were taken from three series, each of thirty experiments. The same experiments were then carried out with methyl alcohol and hydrogen and nitrogen, as in the case of ethyl alcohol and carbon disulphide, yielding the following results from twenty-two experiments :—

Mean temperature corrected......	230°·14.
Probable error	0°·09.
Mean pressure corrected	128·60 atmos.
Probable error................	0·12 „

Here we have, as before, a slight depression of the critical temperature. Experiments were then tried with higher pressure. Forty-seven gave the following means :—

Mean temperature corrected......	227°·92.
Probable error................	0°·10.
Mean pressure corrected	191·40 atoms.
Probable error................	0·07 „

A still higher pressure was then applied. The means of eighteen experiments were—

Mean temperature corrected......	225°·82.
Probable error................	0°·26.
Mean pressure corrected	262·00 atmos.
Probable error................	0·09 „

We have a further depression of the critical point, and as the point was determined with great difficulty we have an increase of the probable error. However, the result confirms the other experiments. The same mode of experiment was then carried out with methyl alcohol and hydrogen and nitrogen as with ethyl alcohol, with the following results.

Table XVI.

Curves VII, Fig. 2, and XV, Fig. 3.

Capillarity of Methyl Alcohol.

T.	P.	Cap. Ht.
232·7	72·8	0
230	64·8	5
220	51·2	52
200	34·8	133
180	23·2	202
160	16·4	257
140	11·9	309
120	7·1	359
100	4·2	402
80	1·9	441
60	..	477
40	..	513
20	..	545
0	..	577

Table XVII.

Curves VIII, Fig. 2, and XVI, Fig. 3.

Capillarity of Methyl Alcohol under Pressure with Hydrogen.

T.	P.	Cap. Ht.
224	123·4	0
220	119·7	27
200	104·2	106
180	90·5	179
160	79·2	237
140	69·1	287
120	61·3	336
100	55·0	283
80	48·1	423
60	42·6	458
40	38·4	493
20	33·8	527
0	29·9	557

In these experiments we see again that increase of pressure never increases the liquidness of the fluid, and never enables it to remain liquid at a temperature above the critical point.

The last liquid examined was carbon tetrachloride, and this was very carefully dried and purified by fractionation and distillation off quick-lime, the purified liquid being kept with the same precautions as were used in the other cases. It was seen, however, that the tetrachloride acted upon the mercury, forming a white crystalline body which crystallised out as the liquid cooled. It appeared to be mercuric chloride, as it dissolved in water; but whether the crystals were pure mercuric chloride or a compound of that body with some other chloride of carbon there was not sufficient obtained to determine. The critical temperature and pressure were determined with twenty different samples, using one quantity only for two or three readings, and the following numbers were obtained :—

Mean temperature corrected......	282°·51.
Probable error................	0°·38.
Mean pressure corrected	57·57 atmos.
Probable error................	0·14 ,,

On attempting to obtain the critical temperature under pressure it was found that the hydrogen at once dissolved under pressure, and not only dissolved, but formed a compound with the tetrachloride. Some curious observations were made on the relation of pressure to chemical combination with this mixture. It was found that for a given temperature and pressure only a certain amount of combination would take place, leaving the excess of hydrogen overlying the tetrachloride quite free. If then more pressure were applied, the manometer would jump up say five atmospheres, and then gradually fall about four or four and a half atmospheres, and again become stable, and this would take place each time, a large portion of hydrogen disappearing for a small permanent rise of pressure. A sudden rise of temperature had somewhat the same effect, but as the temperature could not be varied so suddenly the effect was not so obvious. Several bodies were formed by the action of the hydrogen, the action being capable of being pushed so far as to form chloroform. Nitrogen was used as a pressure substance, and it answered well. The following numbers were obtained from twenty-seven experiments :—

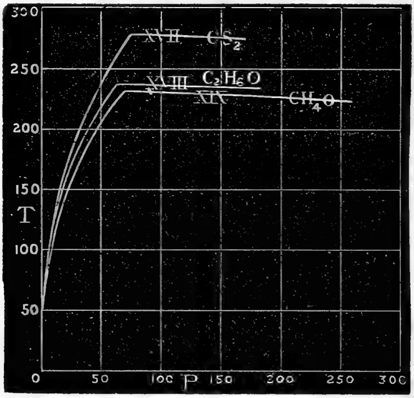
Mean temperature corrected......	277°·56.
Probable error	0°·29.
Mean pressure corrected	142·83 atmos.
Probable error................	0·13 ,,

From this it will be seen that by increasing the pressure to nearly three times the normal, a fall of five degrees in the critical temperature has taken place. This was no doubt due to the surface tension being destroyed by the action of the gaseous molecules, so another series was tried at a lower pressure. Forty-two experiments were done :—

Mean temperature corrected......	282°·50.
Probable error	0°·12.
Mean pressure corrected	83·18 atmos.
Probable error	0·38 ,,

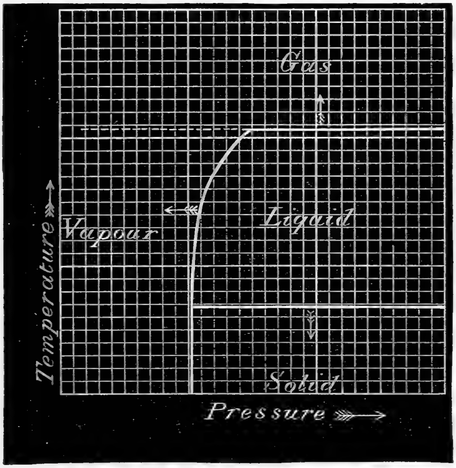
Here we see that a large increase of pressure has not altered the critical temperature at all, as was before seen to be the case with alcohol. A series of capillary measurements was commenced with this liquid, but a series of accidents interfered with the work, and only twelve reliable readings were obtained, and no time has been at my disposal since to finish the work; but sufficient evidence of the course of capillary action has already been gained from the other liquids to draw conclusions as to the liquid state and its limit.

Fig. 4.



Three curves have been drawn to show the depression of the critical temperature with increase of pressure, and these lines have been continued down the curve of vapour pressure to show the break at the critical point. This will be clearly shown in curves Nos. XVII, XVIII, and XIX, fig. 4. The consideration of these results yields a novel mode of looking at the states of matter which I have illustrated in fig. 5. From this it appears we might classify matter under four states; first, the gaseous which exists from the highest temperatures down to an isothermal passing through the critical point and depending entirely upon temperature or molecular velocity; second, the vaporous, bounded upon the upper side by the gaseous state and on the lower by absolute zero, and depending entirely upon the length of the mean free path, because shortening of the mean free path alters the state; third, the liquid bounded upon the upper side by the gaseous state, and on the lower by the solid or absolute zero; fourth, the solid

FIG. 5.



whose condition is also determined by both pressure and temperature. The gaseous state is the only one which is not affected by pressure alone, or in which the molecular velocity is so high that the collisions cause a rebound of sufficient energy to prevent grouping. Another distinction between the gaseous and vaporous states is that the former is capable of acting as a solvent of solids, whereas the latter is not.

The two conclusions arrived at from this work are—

1st. The liquid state has a limit which is an isothermal passing through the critical point.

2nd. The vaporous state can be clearly defined as a distinct state of matter.

To the original distinction between these two states given by Andrews—namely, that of condensibility—I have added another, that of solvent power. A vapour over a liquid holding a coloured solid in solution is colourless, but on passing the critical temperature the whole becomes coloured. In some cases, however, the solid is deposited and redissolved as the temperature rises, showing that the more perfectly gaseous the greater the solvent power. Andrews's distinction compels us to travel along an isotherm, mine requires high pressure; both are thus arbitrary, requiring given conditions, but this is the case with many of the other distinctions used in science.

My thanks are due to my assistant, Mr. Ewing McConechy, for his assiduous aid during the above described investigation.

February 2, 1882.

THE PRESIDENT (followed by THE TREASURER) in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Mr. Henry Francis Blanford (elected 1880) was admitted into the Society.

The following Papers were read :—

I. "Sur les Surfaces Homofocales du Second Ordre." By Lieut.-Colonel A. MANNHEIM, Professor in the École Polytechnique. Communicated by Dr. HIRST, F.R.S. Received January 19, 1882.

Un ellipsoïde (O) étant donné, on sait que par un point quelconque de l'espace, on peut faire passer trois surfaces du second ordre qui lui sont homofocales. La connaissance de l'ellipsoïde (O) entraînant la connaissance de ces surfaces homofocales, il existe des liaisons géométriques entre (O) et ces surfaces.

Je me propose d'établir, parmi ces liaisons, celles qui permettent d'obtenir les rayons de courbure principaux des trois surfaces homofocales. Pour cela, j'appliquerai d'abord un théorème que j'ai eu l'honneur de communiquer à la Société Royale (séance du 16 Juin, 1881) et dont je vais rappeler l'énoncé :

Un angle de grandeur constante, circonscrit à un ellipsoïde donné et dont le plan est normal à cette surface en chacun des points de contact des côtés de cet angle, se déplace de façon que son sommet reste sur l'ellipsoïde (E) *homofocal à l'ellipsoïde donné : ce sommet décrit une ligne de courbure de* (E).

Appelons c le sommet de l'angle mobile, $c\,a$, $c\,b$, ses deux côtés et a et b les points de contact de ces côtés avec l'ellipsoïde (O). L'angle $a\,c\,b$ n'est autre que l'une des sections principales du cône circonscrit à l'ellipsoïde (O) et dont le sommet est c. Si l'on prend un ellipsoïde homofocal à (O) et si on lui circonscrit de même un cône de sommet c, on sait que le plan de l'angle $a\,c\,b$ est aussi le plan d'une des sections principales de ce cône.

Appelons $c\,a'$, $c\,b'$, les génératrices qui forment cette section principale. On peut de même considérer une suite d'ellipsoïdes homofocaux à (O) et l'on aura pour chacun d'eux des droites telles que $c\,a$, $c\,b$,

$c\,a'$, $c\,b'$, &c. D'après ce que nous venons de rappeler, *toutes ces droites sont dans le même plan, a c b.*

Par le point c (fig. 1), élevons la droite G perpendiculairement au plan $a\,c\,b$. Les droites $c\,a$, $c\,b$, G forment un trièdre, que nous allons entraîner en même temps que l'angle $a\,c\,b$ et qui reste de grandeur invariable pendant le déplacement de cet angle. La droite G, ainsi entraînée, reste tangente en son point c à la ligne de courbure E décrite par ce point.

La caractéristique du plan de la face ($c\,a$, G) est la droite $c\,a$, car cette droite passe par les points où cette face touche E et l'ellipsoïde (O). Le lieu des positions du côté $c\,a$ est alors la surface développable enveloppe du plan ($c\,a$, G). Nous appellerons (a) la courbe, lieu des points de contact, tels que a, de cette surface développable et de (O).

Prenons cette courbe (a) comme directrice d'une normalie à l'ellipsoïde donné. Pendant le déplacement du trièdre le plan $a\,c\,b$ contient successivement une génératrice de cette normalie. Sa caractéristique passe alors par le point α, où il touche cette normalie. Mais la tangente en a à (a) et la tangente $a\,c$ sont deux tangentes conjuguées relativement à (O) ; le plan $a\,c\,b$ est alors un plan central de la normalie et le point α est le point central pour la génératrice $a\,\alpha$ de cette surface.

Le point α est aussi le centre de courbure de la courbe de contour apparent de l'ellipsoïde (O) projeté du point c sur un plan mené en a perpendiculairement à $c\,a$.* De même, en considérant des ellipsoïdes homofocaux à l'ellipsoïde (O) on aura pour les points a', a'' . . . . des centres de courbure α', α'' . . . . tels que α. Tous ces points sont aussi sur la caractéristique du plan $a\,c\,b$, c'est-à-dire qu'ils appartiennent à une même droite.

Ce que nous venons de dire est applicable aux centres de courbure correspondant aux points b', b'' . . . . tels que b. Nous avons alors ce théorème :

Les centres de courbure des courbes de contour apparent d'une suite d'ellipsoïdes homofocaux, projetés coniquement d'un même point c *sur des plans issus des points* a, a′ . . . . b, b′ . . . . *et perpendiculaires respectivement aux tangentes* c a, c a′ . . . . c b, c b′ . . . . *qui sont dans un même plan doublement normal à ces ellipsoïdes, appartiennent à une même droite.*

Nous appellerons 1 cette droite (fig. 1). Puisque la droite 1 est la caractéristique du plan mobile $a\,c\,b$, et que ce plan reste constamment normal à la courbe E, nous voyons que :

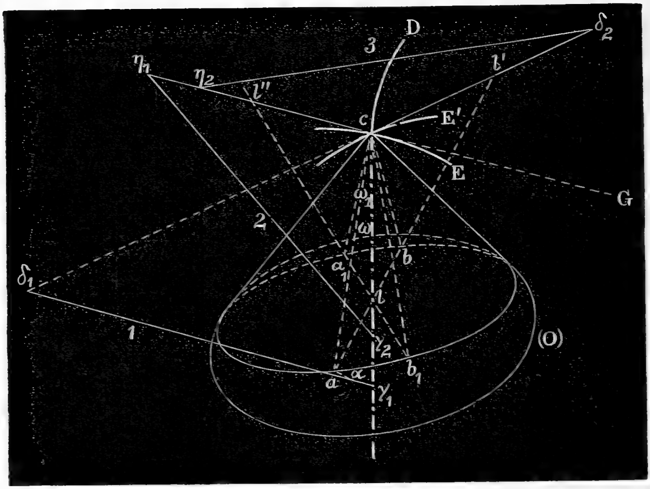
La droite 1 *est l'axe de courbure de la courbe* E.

Et alors :—

Le point γ_1, *où elle rencontre la normale en* c *à l'ellipsoïde* (E) *est l'un des centres de courbure principaux de cette surface.*

* Voir mon "Cours de Géométrie Descriptive," p. 300 et suivantes.

FIG. 1.



La courbe E est l'intersection de cet ellipsoïde et d'un hyperboloïde homofocal (D). *La droite* 1 *rencontre alors la normale en* c *à cet hyperboloïde en un point* δ_1, *qui est un centre de courbure principal de cet hyperboloïde.*

Nous n'avons considéré jusqu'à présent que l'angle $a\ c\ b$, section principale du cône de sommet c circonscrit à l'ellipsoïde (O). Prenons maintenant l'autre section principale, $a_1\ c\ b_1$, de ce cône et supposons qu'on déplace le sommet c sur l'ellipsoïde (E), de façon que l'angle $a_1\ c\ b_1$ reste de grandeur constante ; le plan de cet angle restant toujours doublement normal à cet ellipsoïde. Le sommet c décrit alors sur (E) la ligne de courbure E′ de cette surface et en raisonnant comme précédemment nous déterminons la droite 2, axe de courbure de E′.

La droite 2 *rencontre au point* γ_2 *la normale en* c *à l'ellipsoïde* (E), *et au point* η_1 *la normale en* c *à l'hyperboloïde* (H) *homofocal à* (O), *et qui coupe* (E) *suivant la ligne de courbure* E′. *Les points* γ_2 *et* η_1 *sont des centres de courbure principaux.*

Au moyen des droites 1 et 2 nous avons donc déterminé les deux centres de courbure principaux γ_1, γ_2 de l'ellipsoïde (E), et le problème de la détermination des éléments de courbure de cette surface est ainsi achevé.

Il n'en est pas de même pour les hyperboloïdes (D) et (H).

Pour chacune de ces surfaces nous n'avons encore déterminé qu'un seul centre de courbure principal : occupons nous maintenant de déterminer les deux autres.

L'illustre Chasles, dans son *Résumé d'une théorie des surfaces du* *second ordre homofocales*,* est arrivé au théorème suivant, qu'il énonce ainsi :

Etant données deux surfaces homofocales A *et* A′ ; *si on leur circonscrit deux cônes ayant le même sommet : la courbe de contact de la surface* A *sera la focale d'une surface inscrite dans* A′ *suivant la courbe de contact de celle-ci.*

Appelons (S) la surface ainsi inscrite dans A′ et menons par le sommet du cône un plan sécant. La section faite dans (S) par ce plan est doublement tangente à la section faite dans A′ par ce même plan. Ceci est vrai, quel que soit le plan sécant ; il en résulte, lorsque le sommet du cône vient sur A′, que :

Si l'on a une surface du second ordre A *et un cône qui lui soit circonscrit, la surface du second ordre* (S), *qui a pour focale la courbe de contact de* A *et de ce cône, et qui est tangente au sommet de ce cône à une surface homofocale à* A, *a*, *avec cette surface en ce point, un contact du troisième ordre.*

Supposons que le sommet du cône soit dans l'un des plans principaux de A ; la courbe de contact de A et de ce cône, c'est-à-dire la focale de (S), est alors rencontrée normalement par ce plan principal ; ces points de rencontre avec ce plan principal sont alors les foyers de la section faite dans (S) par ce plan. Nous sommes alors amenés au théorème suivant, qui a déjà été énoncé ainsi par M. Faure.†

Deux coniques homofocales étant données, si, d'un point m *de l'une, on même deux tangentes à l'autre et que l'on trace une conique passant par le point* m *et ayant pour foyers ces points de contact, elle aura avec la première un contact du troisième ordre au point* m.

Reprenons maintenant l'ellipsoïde (O) et l'ellipsoïde (E) qui lui est homofocal. Projetons ces surfaces sur le plan $(a\ c\ b)$ qui est le plan d'une section principale de (E). En vertu d'un théorème connu, les lignes de contour apparent de (O) et de (E) sur ce plan sont deux courbes homofocales. Mais la ligne de contour apparent de (E) a, pour rayon de courbure en c, le rayon de courbure principal, $c\gamma_2$ de (E) : on aura donc ce rayon $c\gamma_2$ en appliquant le théorème de Faure. Voici la construction qui, sur le plan $(a\ c\ b)$ donne ce rayon de courbure : au point a on élève une perpendiculaire à $a\ c$. Du point où cette droite rencontre la normale $c\gamma_1$ on élève une perpendiculaire à cette normale. Cette perpendiculaire rencontre $c\ a$ en un point que l'on joint par une droite au point obtenu de la même manière sur $c\ b$; cette droite rencontre la normale $c\gamma_1$ au point γ_2 qui est le centre de courbure cherché.

On construit de la même manière sur la normale $c\delta_1$ le centre de

* "Comptes Rendus des Séances de l'Académie des Sciences." Séances des 11 et 18 Juin, 1860.

† "Recueil de Théorèmes relatifs aux Sections Coniques." Par M. H. Faure. (Paris : Gauthier-Villars. 1867.)

courbure δ_2 de l'hyperbole qui a pour foyers a et b, et qui passe par le point c. Ce point δ_2 est un centre de courbure principal de l'hyperboloïde (D).

En faisant usage des points a_1, b_1, on retrouve le centre de courbure γ_1 et on détermine sur la normale $c\eta_1$ le centre de courbure principal η_2 de l'hyperboloïde (H).

Nous avons donc déterminé les centres de courbure principaux δ_2, η_2 qui nous restaient à trouver.

La droite δ_2, η_2 *est l'axe de courbure de la courbe d'intersection* D *des deux hyperboloïdes* (D) *et* (H).

Comme on a pu le remarquer, en même temps que nous déterminions les points δ_2, η_2 nous avons retrouvé les centres de courbure principaux de l'ellipsoïde (E).

Ces points γ_1, γ_2 établissent donc une liaison entre les constructions résultant des deux théorèmes absolument différents d'où nous sommes partis. Vérifions directement cette liaison et pour cela démontrons deux lemmes.

1°. *On donne un angle* m c n (*fig.* 2) *et un point fixe* i *de sa bissectrice. Par le point* i *ou mène la transversale* m n *et des points* m, n, *on élève respectivement des perpendiculaires aux côtés de l'angle. Ces perpendiculaires rencontrent la bissectrice aux points* m′, n′ : *le conjugué harmonique* i′ *de* c, *par rapport à* m′, n′ *est le même quelle que soit la transversale* m n.

En effet, on a
$$\frac{1}{cm}+\frac{1}{cn}=\frac{2\,.\cos\alpha}{ci};$$

en appelant α la moitié de l'angle donné. Il résulte de là :

$$\frac{1}{cm'\cos.\alpha}+\frac{1}{cn'\cos.\alpha}=\frac{2\,.\cos\alpha}{ci},$$

d'où
$$\frac{1}{cm'}+\frac{1}{cn'}=\frac{2\cos^2\alpha}{ci}.$$

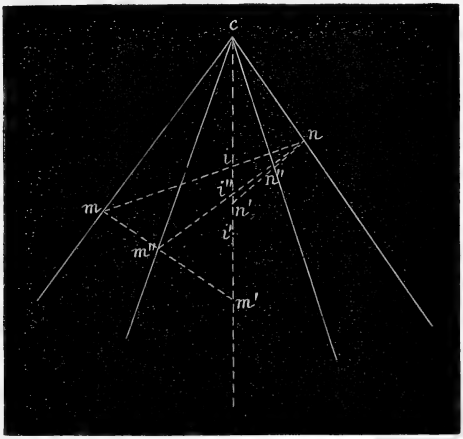
Mais le premier membre de cette égalité est égal à $\frac{2}{ci'}$, on a donc

$$ci'=\frac{ci}{\cos^2\alpha}.$$

Cette valeur de ci' étant indépendante de la direction de $m\,n$, le lemme est démontré.

2°. *On donne deux angles* m c n, m″ c n″ (*fig.* 2) *ayant même sommet* c *et même bissectrice* c i. *Du point fixe* i *on mène une transversale* m n *qui rencontre les côtés de l'un des angles en* m, n. *De ces points on élève respectivement à ces côtés les perpendiculaires* m m″, n n″. *Ces droites rencontrent les côtés du second angle en* m″, n″ : *la droite* m″ n″ *coupe la*

FIG. 2.



bissectrice ci *en un point* i'' *qui reste fixe, lorsque* m n *tourne autour de* i.

En effet, on a:
$$\frac{1}{cm}+\frac{1}{cn}=\frac{2\,.\cos\alpha}{ci}$$

d'où
$$\frac{1}{cm''}+\frac{1}{cn''}=\frac{2\cos\alpha\,.\cos\,(\alpha-\beta)}{ci},$$

en appelant β la moitié de l'angle $m''cn''$.

Mais le premier membre de cette égalité est égal à $\frac{2\cos\beta}{ci''}$. On a donc
$$\frac{1}{ci''}=\frac{\cos\alpha\,.\cos\,(\alpha-\beta)}{ci\,.\cos\beta}.$$

Cette valeur de ci'' étant indépendante de la direction de $m\ n$, le second lemme est démontré.

Reprenons le cône circonscrit à (O) et dont le sommet est c (fig. 1). Appelons l le point où le plan $(a\ b,\ a_1\ b_1)$ rencontre la normale $c\gamma_1$. Faisons tourner le plan $a_1\ c\ b_1$ autour de $c\ l$ pour le faire coïncider avec le plan $a\ c\ b$. Désignons par ω l'angle $l\ c\ a$ et par ω_1 l'angle $l\ c\ a_1$; nous supposerons ω plus grand que ω_1. Ainsi amenés en coincidence les angles $a\ c\ b$, $a_1\ c\ b_1$ forment, sur le plan $a\ c\ b$, une figure analogue à la figure (2).

Il résulte du second lemme que le centre de courbure γ_1 peut s'obtenir, comme précédemment, en menant sur le plan $a\ c\ b$ et par le point l une droite quelconque. Prenons alors la transversale menée par le point l perpendiculairement à $c\ l$. Cette droite rencontre les côtés de l'angle $a\ c\ b$ aux extrémités du grand axe de l'ellipse qui résulte de l'intersection du cône et d'un plan, issu du point l et perpendiculaire à $c\,l$. Appelons (l) cette ellipse de centre l.

Les demi-axes de l'ellipse sont égaux à $c\,l$ tang ω, $c\,l$ tang ω_1. Le rayon de courbure ρ de cette courbe à l'extrémité du grand axe est alors égal à $\frac{cl \operatorname{tang}^2 \omega_1}{\operatorname{tang} \omega}$.

D'après le second lemme le centre de courbure principal du cône correspondant à l'extrémité du grand axe de (l) se projette sur $c\,l$ au point γ_1*.

On a alors $$c\gamma_1 = cl + l\gamma_1 = cl + \rho \operatorname{tang} \omega,$$

et en introduisant la valeur de ρ, il vient :

$$c\gamma_1 = \frac{cl}{\cos^2 \omega_1}.$$

Mais cette valeur de $c\gamma_1$, on l'obtient directement d'après le premier lemme en prenant la section principale $a_1\,c\,b_1$; la vérification que nous nous proposions de faire est donc achevée.

Nous avons en outre les expressions des rayons de courbure principaux des surfaces homofocales à (O), ainsi :

$$c\gamma_1 = \frac{cl}{\cos^2 \omega_1}, \qquad c\gamma_2 = \frac{cl}{\cos^2 \omega}.$$

De la même manière en appelant l' et l'' les points de rencontre du plan $(ab, a_1\,b_1)$ avec les normales $c\delta_1$, $c\eta_1$ on a :

$$c\delta_2 = \frac{cl'}{\sin^2 \omega}, \qquad c\eta_2 = \frac{cl''}{\sin^2 \omega_1}.$$

Pour déterminer $c\delta_1$ et $c\eta_1$, nous n'avons qu'à considérer le demi-angle compris entre les asymptotes de l'ellipse (l). Appelons ϕ cet angle. On a :

$$\operatorname{tang}^2 \phi = \frac{-\overline{cl}^2 \operatorname{tang}^2 \omega_1}{\overline{cl}^2 \operatorname{tang}^2 \omega} = -\frac{\operatorname{tang}^2 \omega_1}{\operatorname{tang}^2 \omega},$$

d'où $$\cos^2 \phi = \frac{\operatorname{tang}^2 \omega}{\operatorname{tang}^2 \omega - \operatorname{tang}^2 \omega_1},$$

et par suite

$$c\delta_1 = \frac{cl'(\operatorname{tang}^2 \omega - \operatorname{tang}^2 \omega_1)}{\operatorname{tang}^2 \omega}, \qquad c\eta_1 = \frac{cl''(\operatorname{tang}^2 \omega - \operatorname{tang}^2 \omega_1)}{\operatorname{tang}^2 \omega_1}.$$

Il faut remarquer que δ_2 et le point l' sont par rapport à c d'un même côté sur la normale cl', et que le centre de courbure δ_1 est de côté différent si nous supposons que δ_1 et δ_2 soient les centres de cour-

* Cette perpendiculaire à cl qui donne le point γ_1 remplace la droite 1, dont nous avons parlé précédemment.

bure principaux de l'hyperboloïde à une nappe (D) qui est une surface à courbures opposées.

Au moyen de ces valeurs, on vérifie tout de suite le théorème de Lamé qui consiste en ce que *le produit* $c\gamma_1 \times c\delta_2 \times c\eta_1$ *est égal à moins le produit* $c\gamma_2 \times c\delta_1 \times c\eta_2$.

Puisque les rayons de courbure principaux $c\gamma_1$, $c\gamma_2$ ne dépendent que du segment $c\,l$ et des angles compris entre les génératrices qui forment les sections principales du cône de sommet c, on a le théorème suivant :

On donne un cône du second ordre de sommet c, *un point* l *sur l'un de ses axes, et par ce point on mène un plan arbitraire qui coupe le cône suivant une certaine courbe. Le long de cette courbe on inscrit dans le cône une surface du second ordre quelconque, et l'on construit la surface homofocale à celle-ci qui passe en* c *et qui a pour normale en ce point la droite* c l. *Cette surface et toutes les surfaces analogues, que l'on obtient en faisant varier le plan sécant mené par* l *et les surfaces du second ordre inscrites, sont osculatrices entr'elles au point* c.

Reprenons la ligne de courbure E de l'ellipsoïde (E), cette ligne étant le lieu du sommet de l'angle constant $a\,c\,b$, il résulte de l'expression de $c\gamma_2$ que :

Les rayons de courbure tels que $c\gamma_2$ *des sections faites dans* (E) *par des plans normaux à* E *sont proportionnels aux segments tels que* c l.

La ligne de courbure E peut être engendrée, comme nous l'avons dit en commençant, en employant l'un quelconque des ellipsoïdes homofocaux à (O). Parmi ceux-ci nous pouvons prendre celui qui, limité à l'ellipse focale de (E), est infiniment aplati et appliquer le résultat précédent. Nous voyons alors que :

Les rayons de courbure, tels que $c\gamma_2$, *des sections faites dans* (E) *par des plans normaux à* E *sont proportionnels aux segments compris sur ces rayons entre les points de* E *et les points où ces rayons rencontrent le plan de l'ellipse focale de* (E).

Comme les plans principaux d'un ellipsoïde déterminent sur une normale quelconque de cette surface des segments proportionnels, *on peut remplacer dans cet énoncé le plan de l'ellipse focale par l'un quelconque des plans principaux de l'ellipsoïde.*

Appelons n le point où la normale $c\,l$ rencontre le plan de l'ellipse focale de (E). Puisque les rayons de courbure tels que $c\gamma_2$ pour les points de E sont proportionnels à $c\,l$ et à $c\,n$, ces segments sont proportionnels entr'eux. On a alors ce théorème :

Les normales à (E), *issues des points de* E, *sont partagées par les plans polaires de ces points pris par rapport à des ellipsoïdes homofocaux à* (E), *en segments proportionnels.*

Cherchons comment varient pour les points de E les rayons de courbure, tels que $c\gamma_1$, des sections faites dans (E) par des plans normaux à cette surface et tangents à E.

On sait, depuis Dupin,* que le produit des rayons de courbure principaux en un point d'une surface de second ordre est inversement proportionnel à la quatrième puissance de la distance du centre de la surface au plan tangent en ce point.

Appelons $o\,p$ la perpendiculaire abaissée de o sur le plan tangent en c à (E). On a alors $c\gamma_1 \times c\gamma_2 = \frac{\text{const}^e}{\overline{op}^4}$.

Et comme le produit $op \times cn = \text{const}^e$, on a donc

$$c\gamma_1 \times c\gamma_2 = \text{const}^e \times cn^4.$$

Mais pour les points de E les rayons de courbure tels que $c\gamma_2$ sont proportionnels à $c\,n$; d'après cela nous retrouvons ce théorème connu.

Les rayons de courbure, tels que c γ_1, *des sections faites dans* E *par des plans normaux à cette surface et tangents à* E, *sont proportionnels au cube des normales issues des points de cette courbe.*†

Et comme $\frac{cl}{cn}$ est constant pour les points de E, nous ajoutons :

Ces rayons de courbure sont aussi proportionnels aux cubes des segments tels que c l.

D'après cela on peut écrire :

$$\frac{cl}{\cos^2 \omega_1} = \text{const} \times \overline{cl}^3,$$

d'où $$cl \times \cos \omega_1 = \text{const}^e.$$ Ainsi :

Les projections des segments tels que c l *sur les droites telles que* c a_1, *sont de grandeur constante, quelle que soit la position de* c *sur* E.

La ligne de courbure E peut être prise dans l'un des plans principaux de (E) ; on voit ainsi que ce théorème s'applique à deux coniques homofocales.

Prenons arbitrairement un ellipsoïde homofocal à (O). Soit, dans le plan $a_1\,c\,b_1$ la génératrice $c\,a_2$ du cône de sommet c qui est circonscrit à cette surface. On a

$$c\gamma_1 = \frac{cl}{\cos^2 \omega_1} = \frac{cl_1}{\cos^2 \omega_2},$$

en appelant $c\,l_1$ et ω_2 les éléments relatifs à cette surface et qui sont analogues à $c\,l$ et ω_1. Mais $c\,l_1$ est proportionnelle à $c\,n$. Donc le rapport $\frac{cl}{cl_1}$ est constant pour les points de E. On voit alors que $\frac{\cos \omega_1}{\cos \omega_2} = \text{const}^e$; ou en prenant les compléments des angles :

* "Développements de Géométrie," p. 212.

† De ce théorème résulte facilement que :—*Les lignes de contour apparent de* (E), *projeté orthogonalement sur des plans normaux à cette surface et tangents à* E, *sont des ellipses de même aire.*

Les droites telles que c a_1, c a_2, *font avec le plan tangent en* c *à* (E) *des angles dont le rapport des sinus est constant, quelle que soit la position de* c *sur* E.

Ce théorème étant vrai pour la ligne de courbure de (E), qui est dans l'un des plans principaux de cette surface, s'applique à des coniques homofocales ; par conséquent :

Etant données trois coniques homofocales, si d'un point c *de l'une, on mène une tangente à chacune des deux autres : le rapport des sinus des angles, que ces tangentes font avec la tangente en* c *à la première, est constant, quelle que soit la position de* c *sur cette courbe.*

Voici encore un moyen de faire voir comment sont liés entr'eux les centres de courbure principaux des trois surfaces homofocales à (O) qui passent par c.

Dans le plan $(a\ c\ b)$ les points γ_2 et δ_2 sont les centres de courbure de deux coniques qui ont pour foyers les points a et b, et qui passent par c. On sait alors* que le point δ_2, relatif à l'une de ses courbes, est le pôle de la droite $c\ \gamma_2$ par rapport à l'autre courbe. Il résulte de là que la droite $\gamma_2\ \delta_2$ est perpendiculaire à la droite qu'on obtient en prenant la symétrique, par rapport à $c\ \gamma_2$, de la projection du diamètre $o\ c$ sur le plan $(a\ c\ b)$.†

De même pour la droite $\gamma_1\ \delta_1$, elle est perpendiculaire au symétrique, par rapport à la normale $c\ l$, de la projection sur le plan $a_1\ c\ b_1$ du même diamètre $o\ c$. On peut alors dire :

Les droites $\gamma_1\ \delta_1$, $\gamma_2\ \delta_2$, *sont perpendiculaires à la direction suivant laquelle le diamètre* o c *serait réfléchi en* c *si la surface* (E) *était réfléchissante.*

II. "On Measuring the relative Thermal Intensity of the Sun, and on a Self-Registering Instrument for that Purpose." By E. Frankland, D.C.L., F.R.S. Received January 24, 1882.

The thermometric estimation of relative solar intensity, according to the best known means, requires first the determination of the temperature of the air—so-called shade temperature—and secondly, and simultaneously, that of a thermometer with a blackened bulb placed *in vacuo* in the sunshine—sun temperature: the difference

* Voir "Treatise on Conic Sections." By Rev. G. Salmon. (6th edition, p. 56.)

† Pour arriver à ce résultat, il suffit d'appliquer au point δ_2 de la tangente $c\delta_2$, ce théorème dû à M. Ribaucour :—" D'un point m, pris arbitrairement sur la tangente en c à une conique, on abaisse des perpendiculaires sur la polaire de m et sur le diamètre aboutissant en c, elles interceptent, sur la normale en c, un segment égal au rayon de courbure en ce point."

between the two temperatures being taken as a measure of the sun's radiant heat operating at the time and place of the two observations.

The chief sources of error in this method are the difficulty of ascertaining the temperature of the air immediately surrounding the vacuous globe containing the blackened bulb, and the placing of this thermometer under exactly similar conditions at different meteorological stations. How considerable may be the errors arising from these sources will be evident from the following observations and experimental results.

Determination of Shade Temperature.

A thermometer merely shaded from the sun gives, in air of uniform temperature, readings differing very widely from each other according to its surroundings. If it be placed opposite a wall, for instance, upon which the sun is shining, the temperature indicated will be several degrees above what it would be if there were no such object near. I have also observed a difference in its readings when, on the one hand, it is exposed towards a blue sky, or, on the other, towards white clouds. Again, if the thermometer be placed in a louvred box, the readings will be much too high, unless the outside of the box be white; because the box becomes heated by the sun and communicates its heat to the air entering the louvres. Even the colour of the ground beneath the box has considerable influence upon the temperature of the air inside.

A true shade temperature means the temperature of free air in full sunshine; and, strictly, it ought to be ascertained without any shade at all, for, as soon as a shade is created, conditions supervene which often entirely baffle the object of the observer. The shade of a parasol exhibits a different temperature from the shade of a tree, and this again differs widely from that of a house. The temperature of the shade of a sheet of tinfoil is quite different from that of a sheet of writing-paper. Indeed, it may be truly said that every shade has its own peculiar temperature. The following thermometric readings show this effect of the area of shade, and of the quality of the shading material:—

Shade Temperatures.

Beneath larch tree	19·5° C.
,, white parasol	25·0
,, small white paper arch	35·0
,, small arch of bright tinfoil	45·2

Thus shade temperatures, measured during $1\frac{3}{4}$ hours of uninterrupted sunshine in the middle of the day, and within a few yards of the same spot, differed by no less than 25°·7 C. These observations were, however, made at Pontresina, 5,915 feet above sea level, and so wide a range would probably not occur at lower altitudes.

The most effective shading material is, obviously, that which most perfectly reflects solar heat; and of all materials with which I have experimented white paper is the best, white linen and zinc-white being nearly equal to it. The most trustworthy shade thermometer, therefore, is one having its bulb covered with a thin layer of white paper, or, in default of this, the naked bulb may be shaded by a small arch of white paper. So placed, the thermometer will indicate a lower temperature than any obtainable in a similar shade produced by any other material.

The foregoing temperatures were observed when the thermometer was level with the ground, but the readings often rapidly become lower as the instrument is raised. The ratio of the diminution of temperature at increasing heights above the ground is, during sunshine, enormously great within a few feet of the earth. The ground, strongly heated by the sun, powerfully warms the molecules of air in immediate contact with it; these, becoming specifically lighter, rise, and at once begin to share their heat with the colder molecules above them, losing temperature in proportion as they mix with larger and larger volumes of supernatant cold air. The intensity of this effect attains a maximum when the air is calm, and a minimum during a storm. Indeed, these powerful convection currents are readily seen, on a calm sunny day, rising from the ground like the heated air from a stove, but they are scarcely, if at all, visible when a strong breeze is blowing.

In order to be comparable with each other, therefore, observations of shade temperature, whether at the same place or at different stations, should always be made under uniform conditions. That is to say, the thermometers, fully exposed to the air, should be similarly protected from radiant heat, and should be placed either at the level of the ground or at a definite height above it, upon a surface of uniform quality as regards absorbing and reflecting power. I would suggest that the bulb of the thermometer and 2 inches of its stem should be protected from the rain by being placed beneath a sheet-zinc arch of 1-inch span and 4 inches long, painted inside and out with "flatted" zinc-white. The instrument with the arch should be securely fixed horizontally upon a wooden stand 1 foot square, painted on both sides with "flatted" zinc-white, and, in order to avoid the excessively warm air very near the ground, the stand should have a height of 4 feet—an elevation convenient for observation, and one at which the temperature of the air suffers comparatively small decrements per foot of elevation. It should also be at a distance from buildings or trees, and have as free a horizon as possible. By the use of instruments so prepared and mounted, comparative and fairly trustworthy determinations of air or shade temperatures in different localities would be obtained.

Determination of Sun Temperature.

The term sun temperature, as commonly employed, has a very vague meaning. If a body could be placed in sunlight under such circumstances as to absorb heat rays and emit none, its temperature would soon rise to that of the sun itself. But as all good absorbers of heat are also good radiators, the elevation of temperature caused by the exposure of even good absorbers to sunlight is comparatively small. Thus an isolated thermometer, with blackened glass bulb, placed in sunshine, will rarely rise more than 10° C. above the temperature which it marks when screened from direct sunlight. Under these circumstances, however, the thermometer loses heat not merely by radiation, but also by actual contact with the surrounding cold air. If the latter source of loss be obviated a much higher sun temperature is obtained; thus, the blackened bulb inclosed in a vacuous clear glass globe will sometimes, when placed in sunlight, rise as much as 60° C. above the shade temperature, and a still higher degree of heat may be obtained by exposing to the sun's rays the naked blackened bulb of a thermometer inclosed in a wooden box padded with black cloth, and closed by a lid of clear plate glass. Thus I obtained with such a box, on the 22nd of December, in Switzerland,* when the air was considerably below the freezing point, a temperature of 105° C., and a still higher temperature could doubtless be obtained by surrounding the thermometer with a vacuous globe before inclosing it in the padded box. These widely different temperatures, produced under different conditions by the solar rays, show that such observations can be comparative only when the thermometer employed to measure them is always surrounded by the same conditions. Under these equal conditions, however, the relative solar intensities at different times or places, are expressed by the number of degrees through which the sun's rays can raise the temperature of any body—the bulb of a thermometer, for instance—above that of the surrounding air. Various instruments have been contrived for such measurements, but the thermometer with blackened bulb *in vacuo* is the most convenient. As indications of solar intensity, however, its readings are, as I shall proceed to show, of little value if, as is sometimes the case, the instrument be simply placed upon grass, or if the shade temperature be not determined in immediate proximity to the vacuous bulb. The following experiments, made with a blackened bulb *in vacuo* verified at Kew Observatory, show how dependent upon the nature of the surface beneath it are the indications of this instrument. They were all made when the thermometer was placed

* "Proc. Roy. Soc.," vol. 22, p. 319.

horizontally with the stem at right angles to the direction of the sun's rays, and sufficient time was always allowed for the thermometer to assume its proper temperature before each reading was taken.

Tosten Vierod, near Laurwig, Norway.

July 17th. Brilliant sunshine, cloudless sky, strong breeze.

Time.	Position of thermometer.	Temperature.
9.40 A.M.	On green grass	57·3° C.
10.10 ,,	On somewhat parched grass	61·2
10.40 ,,	On bare soil	60·6
11.10 ,,	On staff 5 feet above meadow	50·5
11.40 ,,	On newly-mown grass	56·5
12.40 P.M.	On white paper	73·5
1.10 ,,	On staff as at 11.10	51·5

Wilhelmshöhe, Hesse Cassel.

Time 11 A.M. to 1 P.M. August 16th. Brilliant sunshine.

Position of thermometer.	Temperature.
On staff 5 feet above grass	51·8° C.
On black caoutchouc	54·7
On white paper	68·7
On glass mirror	64·0
On black silk	56·5
On slightly concave metallic mirror	64·0
On grass	58·5

Pontresina, Switzerland.

September 7th. Clear and cloudless sky; breeze.

Time.	Position of thermometer.	Temperature.
1.10 P.M.	On staff 4 feet above ice of Mortaratsch Glacier	43·9° C.
1.30 ,,	On black caoutchouc laid upon glacier	39·0
2.0 ,,	On bare ice of glacier	47·5
2.30 ,,	On white paper laid upon glacier	53·0

Summit of Diavolezza Pass, Switzerland.

September 8th. Clear and cloudless except on horizon.

Time.	Position of thermometer.	Temperature.
10.30 A.M.	On staff 4 feet above snow	48·6° C.
11.0 ,,	On black caoutchouc laid upon snow	39·1
11.30 ,,	On bare snow	61·9
12.0 noon.	On white paper laid upon snow	65·5

Bellagio, Italy.

September 17th. Clear sky except near horizon. Air very moist and calm.

Time.	Position of thermometer.	Temperature.
10.30 A.M.	On black caoutchouc laid upon grass	60·0° C.
10.45 ,,	On black merino	59·0
11.15 ,,	On white paper	66·3
11.30 ,,	On white linen	66·0

In some observatories, the blackened bulb *in vacuo* is laid upon grass; but the experiments at Tosten Vierod show that its indications vary, under the same insolation, as much as 4°·7 C. according to the condition of the grass; somewhat parched, and consequently lighter coloured grass, giving a higher temperature than green and moderately long grass, whilst the latter raises the thermometer more than newly-mown grass. These differences result partly from differences of shade or air temperature in the immediate neighbourhood of the vacuous globe of the thermometer, and partly from the different reflecting power of the subjacent surface. With regard to the first of these causes, it must be borne in mind that the solar intensity is measured by the number of degrees through which the blackened bulb *in vacuo* is raised above the temperature of the medium immediately surrounding the vacuous globe. If this medium becomes warmer, the temperature of the blackened bulb will rise in a corresponding measure, and *vice versâ*, although the solar intensity remain the same. Now, the more absorbent the surface upon which the sun's rays fall, the higher, *cæteris paribus*, will be the temperature of the air resting upon that surface. Thus, with the same solar intensity, the shade or air temperature on white paper was 25°·2 C., on black caoutchouc 28°·5 C., on short grass 22°·7 C., and upon a rock 22°·6 C.; whilst at a height of 4 feet above the grass it was only 17°·9 C.

It is to the second of the causes just specified, however—the different reflecting power of the subjacent surface—that the variations of the sun thermometer under the same solar radiation are mainly due, as is proved by the following observations, in which the shade temperature was always taken under a small paper arch close to the vacuous globe:—

Suburb of Zürich. September 19th.

Time.	Position of thermometer.	Sun temperature.	Shade temperature.	Indicated solar intensity.
11.0 A.M.	Four feet above meadow.	47·3° C.	20·5° C.	26·8° C.
11.20 ,,	On grass	53·3	25·3	28·0
11.30 ,,	On white paper	67·0	25·3	41·7
12.0 noon	On black caoutchouc	59·0	27·0	32·0

These results show that the indications of the black bulb *in vacuo* are profoundly affected by the character of the surface beneath the instrument, the more perfect the reflecting power of that surface, other things equal, the higher the solar intensity indicated. Of all the substances tried, the highly reflecting power of white paper and linen for solar heat was very remarkable, exceeding appreciably that of bright metals, and even of freshly-fallen snow of dazzling whiteness. Of course, lateral reflection produces the same effect, and I found that the indicated solar intensity was increased by no less than 11° C. when the blackened bulb *in vacuo* was placed at a distance of 10 feet in front of a whitewashed wall upon which the sun was shining.

Finally the indications of the solar thermometer are also affected by strong wind, the readings of solar intensity being somewhat lower when the instrument is exposed to the current than when it is sheltered. The cause of this is obvious; the difference of temperature produced by the sun's radiant heat is *really* that between the inner blackened bulb and the glass of the vacuous globe. Now the latter is constantly receiving and absorbing obscure rays of heat from the blackened bulb, and its temperature must therefore always be somewhat higher than that of the surrounding air, which is measured by the shade-thermometer; but the glass globe will obviously maintain a less elevated temperature when it receives the strong impact of the molecules of cooler air in a breeze than when it is surrounded by a still atmosphere. The error thus introduced into the observations by a light breeze, however, does not seem to be serious, for I have not found it to exceed 0°·7 C.; but in a high wind it would probably be more considerable.

The results of the foregoing experiments disclose the precautions necessary to be observed to render such determinations of relative solar intensity fairly comparable and trustworthy. They are the following:—

1. The vacuous globe should always and everywhere be placed upon the same kind of horizontal reflecting surface.

2. The temperature of the air upon this reflecting surface should be taken as the shade temperature, and its observation should be synchronous with that of the sun-thermometer.

3. The horizon all round the instrument should be as free as possible, and there should be, especially, no sunlit walls in such a position as to reflect heat upon the thermometer.

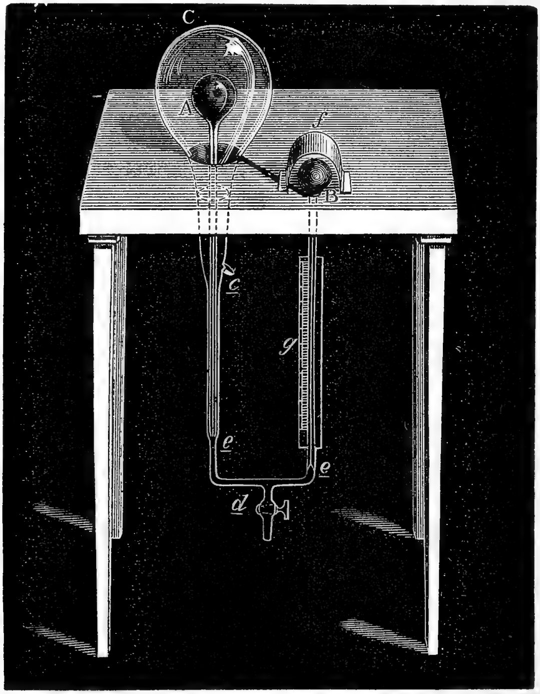
4. As far as compatible with these conditions, the solar thermometer should be sheltered from the wind.

The white surface on which the thermometers are laid need not be of large area. A square foot practically affords to the blackened bulb *in vacuo* a reflective plane of infinite extent, for I have ascertained that the indicated solar intensity is not augmented when the area of white surface is increased fourfold.

There is not much use in having *self-registering* shade and sun thermometers, because the highest temperature of the blackened bulb does not necessarily occur at the time of maximum shade temperature; and, consequently, the maximum solar intensity during any period cannot be found by merely deducting the maximum shade from the maximum sun temperature. Correct observations of maximum solar intensity are, therefore, very laborious with these instruments; and are, I believe, never made in the routine work of a meteorological station. As they afford, however, very interesting data, I have endeavoured to simplify them by contriving an instrument which allows them to be recorded for each day with one reading only.

A Differential Self-Registering Temperature, for measuring relative solar intensity.

This instrument, as seen from the accompanying figure, has considerable similarity to a Leslie's differential air thermometer; but in the new instrument the differential changes in the elasticity of the air of the two bulbs are measured by their action in elevating a column of mercury.



A, B are the two bulbs, 20 millims. in diameter, one of which, A, is blackened in the usual way, and then sealed into the larger clear glass globe, C, which has a small neck at *c* for attachment to a Sprengel pump. As soon as a good vacuum has been obtained, the neck is sealed off before the blowpipe, as shown in the figure. The other bulb, B, is shaded by a small zinc arch, *f*, 3 inches long, painted on both sides with "flatted" zinc-white. These bulbs are connected by a tube bent twice at right angles and furnished at *d* with a branch and stopcock.

The tube from the bulbs to *e e* is of the diameter of that of a self-registering spirit thermometer, but the remaining part of it is much wider, in order to diminish the friction of the column of mercury moving in it. The upright tube attached to B is provided with a scale, and the usual steel index is enclosed in the capillary part of it. The length of the scale is quite independent of the capacity of the bulbs, provided the volume of that part of the capillary tube in which the mercury oscillates is nearly a vanishing quantity in relation to the volume of the bulbs. It is well to have the two bulbs of nearly the same size, but a difference of capacity does not interfere with the accuracy of the instrument. The difference of the level of the mercury in the two limbs will be exactly proportional (neglecting the volume of the capillary tube) to the difference of temperature in the two bulbs, and the degrees of the scale, *g*, will therefore be equal throughout. The length of these degrees, however, though constant for any one instrument, will vary with the temperature and pressure at which the instrument has been filled, being greater the lower the temperature and the higher the pressure. At 0° C. and 760 millims. mercurial pressure, the difference of mercury level corresponding to 1° C. difference of temperature would be 2·784 millims., and the full length of these degrees may be practically obtained by making the wide portion of the tube longer in the limb A *e* than in B *e*, so that a minute depression of the mercury in A *e* will cause a great rise of the column in B *e*. The relative capacities of the capillary and wide tubes can be readily determined, and the necessary correction made in the readings for the depression of the mercury in A *e*.

The instrument may, however, be so constructed as to make the mercury rise and fall equally in both capillary tubes; in which case the rise in one limb would be accompanied by a corresponding fall in the other, and consequently the indicated degrees on the limb B *e* would be only half as long, 1·39 millims. corresponding to 1° C.—a graduation which is sufficiently open for all practical purposes. As a greater difference than 60° C. between the shade and sun thermometers has never been yet observed, a scale 163 millims. long in the one case, or half that length in the other, is sufficient, except perhaps for observations at very great altitudes.

As shown in the figure, the bulbs are supported upon a firm table, one foot square and of any convenient height. A slot is cut in the table of suitable size to permit of the passage of the U-tube and stopcock, the aperture being subsequently closed by a slip of wood level with the top of the table. This table is painted on both sides with "flatted" zinc-white, and its legs are firmly fixed in the ground, so that it cannot be disturbed by the wind. The branch tube, *d*, should also be anchored to the ground by elastic bands, so as to prevent any movement of the instrument from the same cause. It is, moreover, desirable to surround the table with wire netting.

By means of a funnel and flexible tube, mercury is now introduced cautiously into the U-tube through the stopcock, *d*, until it reaches the zero of the scale, care being taken that both bulbs are at the same temperature (which should be noted) during the operation. The pressure upon the air in the bulbs must then be determined, and employed, together with the temperature, in calculating the length of each degree upon the scale. Once charged, the instrument must thenceforward be kept in its normal position, or nearly so, otherwise the mercury will get into the bulbs, whence it can only be dislodged with difficulty. In transporting the instrument from place to place it is therefore advisable to withdraw the mercury.

The following comparative determinations of solar intensity were made with this instrument, and with the ordinary blackened bulb *in vacuo* read on white paper synchronously with a shade thermometer.

Blackened bulb in vacuo.	Shade temperature.	Solar intensity.	
		Result of duplex observation.	Self-registration of differential instrument.
48°·3 C.	29°·0 C.	19°·3 C.	20°·0 C.
49·0	29·2	19·8	20·5
49·7	29·2	20·5	20·5
46·3	28·7	17·6	16·9
45·9	28·4	17·5	17·5
48·4	29·3	19·1	20·4
50·0	29·7	20·3	20·3
47·0	29·5	17·5	17·7
43·2	27·4	15·8	16·1

February 9, 1882.

THE PRESIDENT in the Chair.

The Right Hon. Henry Fawcett was admitted into the Society.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read :—

I. "Note on Mr. Russell's paper, 'On certain Definite Integrals. No. 10.'" By WILLIAM SPOTTISWOODE, M.A., D.C.L, LL.D., Pres. R.S. Received January 30, 1882.

If in Mr. Russell's paper* we take the standard forms—

$$(a,\ b,\ .\ .\ .)(x,\ 1)^4=(\alpha,\ \beta,\ \gamma)(\lambda x^2+2\mu x+\nu,\ 1)^2,$$

we shall have for eliminating α, β, γ, λ, μ, ν, the five equations :—

$$a=\alpha\lambda^2$$

$$b=\alpha\lambda\mu,$$

$$3c=2\alpha\mu^2+\alpha\lambda\nu+\beta\lambda,$$

$$d=\alpha\mu\nu+\beta\mu,$$

$$e=\alpha\nu^2+2\beta\nu+\gamma,$$

the last of which alone contains γ, and may therefore be omitted for the present purpose. Combining the remaining equations, it will be found that

$$3c\mu-d\lambda=2\alpha\mu^3,$$

from which both β and ν have simultaneously disappeared. Hence we have the three equations—

$$a : \lambda^2=b : \lambda\mu=(3c\mu-d\lambda) : \mu^3,$$

for the elimination proposed. These readily give—

$$a^2d-3abc+2b^3=0.$$

Again, for the sextic—

$$(a,\ b,\ .\ .\ .)(x,\ 1)^6=(\alpha,\ \beta,\ \gamma,\ \delta)(\lambda x^2+2\mu x+\nu,\ 1)^3,$$

* "Proc. Roy. Soc.," vol. 33, p. 258.

we have, omitting as before the last equation, viz., that connecting g and δ—

$$\begin{aligned} a &= \alpha\lambda^3, \\ b &= \alpha\lambda^2\mu, \\ 5c &= \alpha\lambda^2\nu + 4\alpha\lambda\mu^2 + \beta\lambda^2, \\ 5d &= 3\alpha\lambda\mu\nu + 2\alpha\mu^3 + 3\beta\lambda\mu, \\ 5e &= \alpha\lambda\nu^2 + 4\alpha\nu\mu^2 + 2\beta\lambda\nu + 4\beta\mu^2 + \gamma\lambda, \\ f &= \alpha\mu\nu^2 + 2\beta\mu\nu + \gamma\mu. \end{aligned}$$

Combining these, it will be found not only that, as in the case of the quartic,

$$3c\mu - d\lambda = 2\alpha\lambda\mu^3;$$

but also that $$4\mu^2 \,.\, 5d - 3\mu\lambda \,.\, 5e + 3\lambda^2 f = 8\alpha\mu^5,$$

from which both β and ν have simultaneously disappeared. Hence we have for the elimination of α, λ, μ, the four equations:—

$$\begin{aligned} a &= \alpha\lambda^3, \\ b &= \alpha\lambda^2 u, \\ 3c\mu - d\lambda &= 2\alpha\lambda\mu^3, \\ 20d\mu^2 - 15e\lambda\mu + 3f\lambda^2 &= 8\alpha\mu^5, \end{aligned}$$

from which it is easy to derive the two final conditions—

$$a^2d - 3abc + 2b^3 = 0,$$

and $$20a^2b^2d - 15a^3be + 3a^4f - 8b^5 = 0.$$

It would perhaps be difficult to obtain the results for the general case by the present method; but if the question be regarded from a different point of view, we can see not only how many conditions will exist in general, but also what will be their form; and, moreover, we can actually obtain them in any particular case.

The problem is in fact identical with that of finding the conditions under which an equation of the degree $2n$ can be solved by means of an equation of the degree n. To answer this, we have merely to substitute in the equation

$$(a, b, \ldots)(x, 1)^{2n} = 0$$

$x + w$ for x, and equate to zero the coefficients of the odd powers of x. This will give n equations, from which we can of course eliminate w in $n-1$ ways; and the results of the eliminations will consequently be the conditions sought, $n-1$ in number. Applying this to the case of the sextic, we have

$$(a, b, \ldots)(x + w, 1)^6 = 0;$$

and if we equate to zero the coefficients of x^5, x^3, x, we shall have the equations—

$$(a, b)(w, 1)=0,$$

$$(a, b, c, d)(w, 1)^3=0,$$

$$(a, b, c, d, e, f)(w, 1)^5=0.$$

Whence, eliminating w between the first and second of these, we obtain—

$$(a, b, c, d)(b, -a)^5=0,$$

$$(a, b, c, d, e, f)(b, -a)^5=0;$$

or, developing the expressions,

$$a^2d-3abc+2b^3=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

as before, and

$$a^4f-5a^3bc+10a^2b^2d-10ab^3c+4b^5=0 \quad . \quad . \quad . \quad . \quad (2).$$

In order to bring this to the same form as the condition found by the other method, we have only to write, for (2), the following, viz.,

$$3(2)-10b^2(1)=0,$$

which gives $\quad 3a^4f-15a^3be+20a^2b^2d-8b^5=0,$

as before.

It is unnecessary to pursue the subject further, as the method is perfectly general and obvious in its application.

II. "Report of an Examination of the Meteorites of Cranbourne, Australia; of Rowton, Shropshire; and of Middlesbrough, in Yorkshire." By WALTER FLIGHT, D.Sc., F.G.S., of the Department of Mineralogy, British Museum, South Kensington. Communicated by H. DEBUS, Ph.D., F.R.S. Received January 19, 1882.

(Abstract.)

I.—*The Siderites of Cranbourne, near Melbourne, Australia.*

The large masses of meteoric iron found at Cranbourne, near Melbourne, Australia, were known as far back as 1854. The larger block was bought by Mr. A. Bruce, now of Chislehurst, for one sovereign, who determined to present it to the British Museum. The smaller mass, weighing a few hundredweight, became the property of Mr. Abel, and was sent to the International Exhibition of 1862. When the block belonging to Mr. Bruce came to be uncovered and moved it was found to weigh $3\frac{1}{2}$ tons. Some difficulties arose respecting its shipment to England, and eventually Mr. Abel's block was purchased for 300*l.* by the Trustees of the British Museum, and presented to the colony, and the larger mass was sent to this country. They lay 3·6 miles apart; and the major axis of the Bruce meteorite, some 5 English feet, lay exactly in the magnetic meridian of the place.

The Bruce meteorite consists entirely of metallic minerals, and contains no rocky matter whatever. The iron contains no combined carbon, but from 7 to 9 per cent. of nickel, some cobalt, a little silicium, and copper; and, distributed through its mass, rather less than 1 per cent. of bright, apparently square prisms of a phosphide.

Lying on the plates of meteoric iron, which make up the mass, were found thin metallic plates of the thickness of writing paper, of a flexible mineral, which had the composition Fe_5Ni_2. It is this mineral which forms the figures on etched surfaces, and not schreibersite as generally stated. I propose to call this compound Edmondsonite, in memory of the late George Edmondson, the Head Master of Queenwood College, a great lover of science; a man with whom I had the honour to be long and intimately connected.

Nodules of troilite, varying from half an inch to two inches in length, are frequently met with. The composition of the sulphide proved it to be the iron monosulphide beyond question. Occasionally nodules of graphite were noticed, enclosing troilite in curious pointed forms, so that a section resembles the outline of a holly leaf. The prisms already referred to appear to be identical with the mineral to which Gustav Rose gave the name of rhabdite, and to have the composition indicated by the formula $(Fe_4Ni_3)P$. The resemblance between them and the phosphide described by Sidot, and more recently by Mallard, is gone into. A very brittle coarse powder, left by treating the iron with acid, yielded what appears to be schreibersite with the formula $(Fe_2Ni)_7P$. Among the *débris* of the meteorite were occasionally found large brass-coloured oblique crystals; these readily cleave across the base, and have a composition according with the formula $(Fe_9Ni_2)P_2$. There were also curious crystals met with on two or three occasions, apparently square prisms, which, while the sides were quite bright and metallic, had a square centre of a dull, almost black, colour; this also is a phosphide, and has a composition closely according with the formula $(Fe_7Ni_2)P$.

Graphite occurs occasionally, but rarely, as nodules, sometimes as nodules enclosing troilite, in one case in a mass extending over an area 4 inches in length by 2 inches wide. It contained from 0·25 to 0·30 per cent. of hydrogen.

The occluded gases amounted in bulk to 3·59 times the volume of the iron, and consisted of—

Carbonic acid	0·12
Carbonic oxide	31·88
Hydrogen	45·79
Marsh-gas	4·55
Nitrogen	17·66
	100·00

Drawings of the meteoric iron *in situ* accompany the paper.

II.—*The Rowton Siderite or Meteoric Iron.*

The metallic mass next to be described is one of unusual interest in more than one respect: in the first place, before it fell, only one iron meteorite was known to have fallen in Great Britain, while eight stony meteorites that have fallen in the British Islands are in the National Collection; and, secondly, of the more than 300 meteorites which are contained in the collection in the Natural History Museum more than 100 are unquestionably iron meteorites, and of these the fall of seven only has been witnessed.

This iron fell at about twenty minutes to four on the afternoon of the 20th April, 1876, in a turf-field adjoining the Wellington and Market Drayton Railway, about a mile north of the Wrekin, on land belonging to the Duke of Cleveland, at Rowton, near Wellington, Shropshire. A strange rumbling noise was heard in the air, followed instantaneously by a startling explosion resembling a discharge of heavy artillery. Rain was falling heavily at the time. About an hour later a man entering the field had his attention attracted by a hole cut in the ground; he probed it with a stick, when he found a block of meteoric iron weighing $7\frac{3}{4}$ lbs. It had penetrated to a depth of 18 inches; the hole was nearly perpendicular, but the stone appears to have fallen in a south-easterly direction. When removed from the hole the mass was still quite warm.

It is covered with a thin dull black crust of the magnetic oxide, though in certain spots the metallic character of the block is revealed, especially at the point where it struck the earth. It closely resembles the iron of Nedagolla, in India. Some fragments were analysed, and found to contain iron 91·25 and 91·046, nickel 8·582, cobalt 0·371, and a trace of copper.

A part of a nodule of troilite, which was found not to be in the slightest degree magnetic, and was covered with a thin layer of graphite, was submitted to analysis; and there was found sulphur 36·073 per cent., theory requiring 36·36 per cent.

Some fragments of iron were sawn into very thin plates, and the gases contained in them pumped out. The gas collected was 6·38 times the bulk of the iron used, and its composition proved to be—

Carbonic acid	5·155
Hydrogen	77·778
Carbonic oxide	7·345
Nitrogen	9·722
	100·000

A drawing of the Rowton iron, and of a section showing the figures, accompanies the paper.

III.—*The Meteorite of Middlesbrough, Yorkshire.*

During the past year a very beautiful specimen of a meteorite fell near Middlesbrough, at a spot called Pennyman's Siding on the North Eastern Railway Company's branch line from Middlesbrough to Guisbrough, about one mile and three-quarters from the former town. Its descent was witnessed by W. Ellinor and three platelayers, who heard a whizzing or rushing noise in the air, followed in a second or two by a sudden blow of a body striking the ground not far from them; the spot was found to be 48 yards from where they stood. The fall took place at 3·35 P.M. on the 14th March, 1881. No luminous or cloud-forming phenomena are reported. According to Professor Alexander Herschel, who at once visited the spot, the fall appears to have been nearly vertical. The stone was "new milk warm" when found, and weighed 3 lbs. 8¼ oz.; the crust is very perfect and of an unusual thickness, and has scarcely suffered by the fall. The stone forms a low pyramid, slightly scolloped or conchoidal-looking, 6¼ inches in length, 5 inches wide, and 3 inches in height. The rounded summit and sloping sides are scored and deeply grooved, with a polish like black lead in waving furrows running to the base, showing that this side came foremost during the whole of the fusing action of the atmosphere which the meteorite underwent in its flight. The base is equally fused by heat, but is rough, dull brown in colour, and not scored or furrowed. It penetrated the soil to a depth of 11 inches. From experiments made by Professor Herschel it is calculated that it struck the ground with a velocity of 412 feet per second. As it would acquire this velocity by falling freely through half-a-mile, it is evident that little of the original planetary speed with which it entered the atmosphere can have remained over.

The stone contains 9·379 per cent. of nickel-iron, the composition of which was found to be—

Iron	76·99
Nickel	21·32
Cobalt	1·69
	100·00

The percentage of nickel is high; but it is pointed out that in the nickel-iron present in meteoric stones the nickel rises in quantity as the quantity of nickel-iron falls. The remaining constituents consist of rocky matter, amounting to 90·621 per cent., and are soluble silicate 54·315 per cent. and insoluble silicate 36·306 per cent. The soluble silicate appears to be an olivine of the form $2(\frac{1}{3}Fe,\frac{2}{3}Mg)O,SiO_2$, or one closely resembling that which occurs in the Lancé stone, which fell July 13th, 1872, and was examined by Daubrée. The insoluble part is chiefly bronzite, and most closely resembles that which is to be found in the meteorites of Iowa co., Iowa, east of Marengo, which fell 12th February, 1875, and were examined by Dr. L. Smith. The aluminium constituent is doubtless labradorite, and is probably present as some of the occasional chondra which are seen in a microscopic section.

A plate showing three views of the stone accompanies the paper.

February 16, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On Impact with a Liquid Surface." By A. M. WORTHINGTON, M.A. Communicated by Professor OSBORNE REYNOLDS, F.R.S. Received January 27, 1882.

(Abstract.)

The apparatus previously used* by the author for following the progress of the splash of liquid drops impinging on a solid plate has been improved. The main principle of the method by which successive stages are isolated and rendered visible remains the same, viz., instantaneous illumination at any desired stage by means of the primary spark of an induction coil; but the timing of the illumination is now effected by a timing-sphere let fall simultaneously with the solid or liquid sphere whose impact is to be observed. The timing-sphere strikes a plate whose height can be adjusted, and thereby starts the mechanical action which results in the spark.

* "Proc. Roy. Soc.," vol. 25, pp. 261, 498.

The time interval between successive stages of the disturbance can be measured to within a few thousandths of a second.

The significant portion of the whole series of changes in most of the splashes observed is comprised within about one-third of a second. The impact of both solid and liquid spheres has been studied, and is illustrated by several series of drawings which accompany the paper.

Milk drops falling into water were found to produce a similar disturbance to that resulting from the impact of similar water drops, and were used for the sake of distinguishing the original liquid of the drop from that into which it fell. With a drop about 5 millims. in diameter, falling from less than 1 metre, an annular rim is raised at the first moment of impact, bounding a hollow which is afterwards characterised by regularly disposed radial ribs and arms, at the bottom of which the drop descends, passing below the surface and becoming completely submerged, to emerge again at the head of a column of adherent liquid, but with its upper portion apparently unwetted by the liquid with which it has been covered. The column then subsides, and the liquid of the original drop is seen to pass into the well-known vortex ring which descends through the liquid.

The influence of velocity of impact in modifying the phenomenon is shown by the drawings.

When the drop is large, and the fall considerable, the rim thrown up takes the form of a hollow crater-like shell of liquid, the mouth of which closes over the drop, imprisoning air which may remain as a bubble on the surface. This is the bubble seen when large rain drops fall into water. Observations of the bursting of this bubble confirm incidentally the explanation lately given by J. Plateau of the manner of bursting of a soap bubble.

The splash of a milk drop in petroleum and in olive oil is also described. The course of phenomena is very similar to that in water, modified however by the greater or less mobility of the liquids in question.

The impact of solid spheres is then described. The nature of the disturbance produced, with a given velocity of impact, is found to depend entirely on the state of the surface of the sphere.

A polished and perfectly dry sphere of ivory or marble 1 to 3 centims. in diameter, let fall from a height not exceeding 1 metre, is apparently wetted at once, and is seen to be sheathed with liquid before the whole is below the average level of the surface. The disturbance of the surface is very slight.

The same sphere if *rough* or *wet* with the liquid in question, behaves quite differently, making a very deep depression, similar at first to that produced by a liquid drop, which finally becomes an almost cylindrical column of air within the liquid, part of which afterwards rises as bubbles while a portion descends in the wake of the sphere.

The influence of roughness in hindering the spread of liquid over the surface of the impinging sphere is then pointed out.

At the close of the paper an explanation is put forward of the radial ribs, arms, and striæ which are a notable feature of all splashes. Measurements of the annular rim bordering a thin central film, into which a drop falling upon a plate passes,* show that the number of the lobes and arms which are subsequently observed, agrees well with the number of drops into which such an annulus would theoretically tend to split if unhindered by friction with the plate on which it rests, and it is then pointed out that the effect of the connecting film would be exactly such as to counteract the influence of this friction.

In the same way the radial striæ and ribs which characterise the hollow formed round a drop or solid sphere impinging on a liquid surface, are accounted for by the instability of the annular rim of the hollow, which through its tendency to cleave into a definite number of drops, determines a corresponding number of lines of easiest flow, at each of which a rib or arm is developed.

The author has observed that after the details have been once revealed by the method of instantaneous illumination, it is not difficult to identify the broad features of any splash that may occur by attentive observation in continuous light. Such observation may afford valuable information as to the condition of the surface of an impinging solid.

II. "The Minute Anatomy of the Thymus." By Herbert Watney, M.A., M.D. Cantab. Communicated by E. A. Schäfer, F.R.S. Received January 30, 1882.

(Abstract.)

Three short notes relating some of the facts mentioned in this research have been published in the "Proceedings," vol. 27, p. 369; vol. 31, p. 326, and vol. 33, p. 11.

The paper begins with a history of the views which have been held as to the anatomy, physiology, and development of the thymus.

The microscopical sections in many instances were double-stained by hæmatoxylin, by using first a red and then a blue solution; the colours of the solutions depend on the alum used with the hæmatoxylin extract. The red solutions stain the protoplasm of the cells, the connective-tissue, and the granular cells; the blue, the lymphoid corpuscles and the reticulum.

In all mammals the thymus disappears at some period of adult life;

* "Proc. Roy. Soc.," vol. 25, p. 500, fig. 4.

in the bird it disappears generally before adult life; in the reptile and the fish it is found even in very large specimens, although in such cases it is in great measure transformed into connective-tissue.

The fully developed gland is divided into lobes, lobules, and follicles; the follicles, except in earliest embryonic life, are composed of cortex and medulla; the follicles are generally attached to one another, either by cortical or by medullary tissue.

When first developed the thymus is composed at its upper end of a single tube, and below of a number of tubes, some of which are solid, the others hollow; the cells in cross section of the tube vary from two or three to many in number, and are epithelioid in character; the lumen of the tube is at times closely packed with blood-corpuscles, and appears to be a vessel. The follicle first grows by pushing out processes of epithelioid cells. In a subsequent stage the connective-tissue (ensheathing the vessels which enter and leave the follicles) invades the follicles and divides them up; at the same time the follicles increase in size: there is thus an increase in the number of the follicles, which are partially united to one another.

The cortex when first formed is small, but in the fully developed gland is more than twice as large as the medulla; in involution the outer part of the follicle disappears much the more rapidly of the two. As further the cortex is composed chiefly of cells (*thymic corpuscles*), similar to those which are formed in the lymphatics of the thymus, this portion is the more important.

The blood-vessels are disposed in two rings, one of which surrounds the follicle, the other lies just within the margin of the medulla; the cortex contains only fine vessels arranged in a radiating manner; the blood in these vessels flows chiefly to the inner circle of vessels. The centre of the medulla contains only few and fine vessels during growth and the period of full development, but in involution there are many more and larger vessels. The blood-vessels met with in the invading processes of connective-tissue during involution are surrounded by an adventitia of epithelioid cells, so that they look somewhat as if composed of proliferating endothelium; this probably is not the case, as their lumen is unaltered.

There are no lymphatic vessels in the cortex of the follicle, although perivascular sheaths are found on the vessels during the period of involution.

The cortex is composed in great measure of lymphoid cells, supported by a delicate *reticulum*. If sections of the cortex are shaken a second retiform tissue is brought into view, *i.e.*, a branched *network*, composed of finely branched cells, and of coarse threads; these together form an adventitia to the vessels. This network of cells is permanent, and is found in the thymus of adult animals when the organ is undergoing involution. In specimens stained in indigo-carmine and carmine, the *network* is stained of a different colour to the *reticulum.*

The network of the cortex is continuous with a network in the medulla; in the latter situation, however, the cells are large and their processes are coarse. There is a gradual transition between these last and epithelioid connective-tissue corpuscles; and, further, in some places the network assumes the form of multi-nucleated protoplasmic masses not differentiated into cells. In the medulla but few lymphoid cells and only traces of the reticulum are seen, but it contains concentric corpuscles, giant cells, and numerous granular and epithelioid cells.

Granular cells are met with in the later period of embryonic life; they are not readily acted on by ordinary staining solutions; their protoplasm resembles that of the giant cells of the medulla of bone. They are present in four forms:—(1) As polygonal or rounded epithelioid cells, the central part only of the cells being granular; (2) as vacuolated cells, the mass lying in the vacuole being granular; (3) as spherical masses lying in cavities between the branching processes of the connective-tissue corpuscles; and (4) as rounded or club-shaped masses attached (often by fibrillated extremities) to blood-vessels and to newly formed connective-tissue. The first form arises from epithelioid connective-tissue corpuscles, and gives origin to the second and third varieties. The fourth variety forms fibrous tissue, and sometimes forms blood-vessels: the cells of this class are very similar in appearance to certain cells (*Bildungszellen*) which have been described by Ziegler and Tillmanns in pathological new formations.

The giant cells arise in two ways, either from the fusion of several granular cells, or from the branched protoplasmic network.

The concentric corpuscles consist of a central mass and of a capsule; the central mass is at times found passing down the vessel-like prolongations, which are attached to the concentric corpuscles; the capsule is formed of epithelioid cells; these cells are anatomically continuous with the branched connective-tissue corpuscles forming the network; the cells of the network around the concentric corpuscles are larger than in other parts of the medulla. The concentric corpuscles are attached to one another by long coarse threads which have nuclei imbedded in them, or by bands of fibrous tissue. They are finally transformed into bands of fibrous tissue containing vessels. The central part of the concentric corpuscles is never penetrated by injection, although the outer part of the capsule often contains vessels, as the capsule of epithelioid cells in its growth may surround a vessel. The smaller concentric corpuscles are composed of one or more granular cells, surrounded by epithelioid connective-tissue corpuscles; they arise from these two sources.

Ciliated epithelium is found lining cysts in the thymus of the dog.

The cysts are formed by the vacuolation and degeneration of the central cells of the small concentric corpuscles; they are filled with degenerated epithelium, or with hæmoglobin masses. The borders of the cysts are at first formed of epithelioid cells, but there is a gradual transition from these flattened cells to ciliated epithelium.

The process of involution is very gradual; the first steps are begun in fœtal life. The main factors are:—(1) The formation of fibrous tissue within the follicle; this arises by means of the granular cells, of the giant cells, and of the connective-tissue corpuscles; (2) the increase in the inter-follicular connective-tissue, and the deposit of plasma cells in this tissue; the plasma cells are here the forerunners of fat cells; they are identical with many of the colourless cells of the medulla of bone, and stain in a very characteristic manner in indigo-carmine and carmine solutions; (3) the invasion of the inter-follicular connective-tissue and plasma cells into the follicle. There is no fatty degeneration of the cells of the thymus.

There is considerable difference in size between the *thymic corpuscles* and the colourless blood-corpuscles in amphibia and reptiles, and still greater difference in the bird and the fish. The differences between the thymus of birds, reptiles, and fishes, and that of mammals are also pointed out in the paper.

Hæmoglobin is found in the thymus contained either in cysts, or in cells which are situated near to, or form part of, the concentric corpuscles. The hæmoglobin in the cells varies from granules to masses exactly resembling coloured blood-corpuscles; these masses are oval in the bird, reptile, and fish, but circular in all mammals except the camel.

The lymph issuing from the thymus was obtained by tying the vessels; it contains more colourless cells than do the large lymphatics of the neck, and, in addition, contains cells inclosing hæmoglobin in the form of granules, or in masses resembling coloured blood-corpuscles.

The physiological conclusions arrived at are: that the thymus forms one source of colourless blood-corpuscles, and that the cells containing hæmoglobin masses form coloured blood-corpuscles. This view is supported by the inclosed masses being identical in form with, though often smaller in size than, the coloured blood-corpuscles; is further supported by finding such cells in the lymphatics, in the blood, in the lymphatic glands, the medulla of bone, and the spleen; and is still further supported by the development of the blood in the chick, and in the connective-tissue of young mammals.

III. "On the Influence of the Galvanic Current on the Excitability of the Motor Nerves of Man." By AUGUSTUS WALLER, M.D., and A. DE WATTEVILLE, M.A., B.Sc. Communicated by J. S. BURDON SANDERSON, M.D., F.R.S. Received February 2, 1882.

(Abstract.)

The object of the experiments described in this paper is to demonstrate on the living nerves of man, alterations of excitability during and after the passage of a galvanic current, and to determine how far such alterations concord with the results obtained by Pflüger and other physiologists on the exsected frog's nerve.

In order to subject the nerve to the influence of a "polarising" current, and to test its excitability by means of induction currents, the secondary coil is introduced into the galvanic circuit, so that the points of entrance and exit of the two currents (galvanic and induced) coincide at the two electrodes. One electrode, N, is applied over the nerve, the other, F, to any distant part of the body.

The density of the current which passes in the nerve is much greater in the "polar" region (that is, immediately under the electrode N) than in the adjacent region, which may be termed the "peri-polar" zone, and the authors' experiments go to prove that these two regions are to be physiologically distinguished by the fact that their electrotonic states are opposed.

The authors observe that the excitatory effect of an induction current is increased during the passage of a galvanic current in the same direction, diminished during its passage in an opposite direction, that the increase is greater when both currents are directed from F to N than when both are directed from N to F, and that the diminution is greater when the induction current is from F to N and the galvanic current from N to F than when these two currents flow in the reverse direction.

These results admit of a complete explanation, for which the grounds are stated in the paper. During the passage of the galvanic current from F to N katelectrotonus is set up in the polar region and anelectrotonus in the peri-polar region; during the passage of a galvanic current from N to F the polar region is in anelectrotonus, the peri-polar in katelectrotonus. At the passage of the induction current from F to N excitation is made in the polar region, at its passage from N to F in the peri-polar region.

Some subsidiary phenomena are discussed, and an experimental proof is given of the physiological reality of the above changes.

In addition to the induction current the authors have used the

make and break of the battery current as the test of excitability. They find that the effect of the make excitation is increased when it falls upon a katelectrotonic region, polar or peri-polar, that the effect of the break excitation is diminished when it occurs in an anelectrotonic region, polar or peri-polar, and that increase and diminution are more marked in the case of the polar than that of the peri-polar region.

They also tested the polar region by mechanical excitation, and obtained evidence of increased excitability at the kathode, of diminished excitability at the anode.

The authors have also observed "after-effects" of polarisation corresponding with the after-effects of electrotonus in the frog's nerve as described by Pflüger.

The experiments were for the most part made on the peroneal nerve, which was selected on account of its superficial course, and the facility with which the muscular responses could be recorded graphically.

IV. "On the Excretion of Nitrogen by the Skin." By J. BYRNE POWER, L.C.P.I. Communicated by Professor EMERSON REYNOLDS, F.R.S. Received February 7, 1882.

During the years 1877–78, I conducted a series of experiments on the excretion of nitrogen by the skin. Some of the data then obtained were communicated at the Dublin Meeting of the British Association, but I have since extended the inquiry, and now beg to submit an account of the investigations.

The results obtained by various experiments as to the existence of nitrogen in the sweat have been contradictory. Voit,* Ranke,* Parkes,† and others, relying on indirect methods, have denied its existence, finding that the quantity excreted by the kidneys and intestinal tract was equal to, and in some cases even exceeded, that ingested, therefore leaving no room for any excretion by the skin.

On the other hand, Anselmius,‡ Berzelius,§ Favre,|| Funke,¶ and

* "Schmidt's Jahrb.," Bd. cxvii, pp. 1—10. Voit made further experiments on doves with confirmatory results. On the other hand, Seegen and Nowak made subsequent experiments upon dogs with opposite results; these again are contravented by Gruber ("Virchow and Hirsch, Jahrgang," Bd. I, 1881, p. 163). I do not myself believe that experiments on the lower animals are conclusive on this point in human physiology.

† "The Lancet," 1871, vol. i, p. 400.

‡ Berzelius, "Traité de Chimie." Traduit par M. Esslenger. Tom. vii, p. 324. Paris: 1833.

§ *Op. cit.*, p. 325.

|| "Archiv Gén. de Méd.," 1853, Tom. ii, pp. 1—20.

¶ "Beiträge zur Kenntniss der Schweissecretion." Moleschott's "Untersuchungen zur Naturlehre," iv, 36.

others who have analysed portions of the sweat collected by different methods have found nitrogen, though Schottin and Ranke failed to do so. Funke, by his experiments upon himself and his two pupils, published in 1858, not only found nitrogen in the sweat, but also proved its existence as urea, and was the first to make an estimation of the quantity excreted by the skin of the entire body in a given time. Adopting Schottin's method, he collected, by means of a caoutchouc sleeve, the sweat excreted by the arm in a given time; and, having filtered, he estimated the quantity of nitrogen present by the combustion process. Then, having established by measurement a ratio between the superficies of the arm and that of the entire body, he calculated the entire cutaneous excretion. Dr. Fleming,* adopting the same method, arrived at almost identical results. I may add that Dr. Fleming's experiments were made subsequently to mine.

In addition to the unsatisfactory character of all indirect proofs, the investigations of Voit, Ranke,† Parkes, and others seem liable to a further objection, arising from the extreme difficulty of ascertaining the exact quantity of nitrogen ingested. Again, as already noted by Parkes, the amount of nitrogen excreted, due to waste of animal tissue during the experiment, cannot be determined. These objections seemed to me to make such negative results of doubtful value upon this point; and Professor Parkes' conclusion that, "apart from detached skin structures the balance of evidence is against the passage of nitrogenous substances by the human skin," to my mind, at least, required confirmation. As regards the direct evidence of nitrogen in the sweat the researches of Funke, confirmatory of those of Anselmius, Berzelius, Favre, and others seemed to me to be conclusive on the point.

Funke's method is the only one by means of which an estimation of the entire cutaneous excretion in a given time has been made, and it alone required re-examination. Funke's method seemed to me to be open to the following amongst other objections: first, the uncertainty attaching to the relative measurement of the superficies of the arm and that of the entire body; secondly, that arising from the two underlying assumptions—(*a*) assumed equality of secretive power of rest of body to that of arm, (*b*) assumed identity of chemical composition of sweat from the arm with that excreted from the rest of body. Considering these grave objections to Funke's method, and the general uncertainty as to any nitrogen being excreted by the skin, I determined, if possible, to ascertain the quantity of nitrogen excreted by the entire skin in a given time without reference to measurement or actual amount of fluid sweat excreted.

* "Journ. Anat. and Physiol.," vol. xiii, p. 454.

† Ranke, as above alluded to, endeavoured to obtain nitrogen directly by analysis of the sweat, and failed to do so, but seems to have mainly relied on the indirect argument.

I shall now briefly state the mode of collecting the excretion which I adopted. Having first tested the atmosphere of the ward in which I was about to operate, to ascertain that it did not contain free ammonia in any quantity, I placed upon one of my hospital beds an india-rubber sheet, and over it another sheet of pure linen, upon which the person experimented upon lay. Over his body was placed a wooden cradle or canopy, covered outside with a thick felt, and lined inside with linen, which coverings were to be carefully adjusted round his neck. To raise the temperature within the canopy I used the lamp-furnace invented by the late Surgeon-Major Wyatt, the flue from which fitted accurately through a hole in the coverings guarded by a wooden ring. Considering the spirit lamp of Wyatt's furnace objectionable for many reasons, I substituted a Bunsen gas-burner. To insure the regular renewal of the air within the canopy, and to prevent its saturation, as well as to collect any free ammonia which might be evolved, I introduced a tube leading from a Bunsen air-pump, which tube was connected with two glass towers filled with large glass beads, and charged with half an ounce of dilute hydrochloric acid of known strength. Through another hole in the canopy I introduced a hydrometer, by which I was enabled to observe the temperature, and calculate the degree of saturation of the atmosphere within. As the gas, water, and reagents employed contained some small portion of nitrogen, my first task was to ascertain the constant error arising from this source. To effect this I performed three blank experiments, omitting only the introduction of the person to be experimented upon. The result was that I obtained a small quantity of nitrogen, nearly equal in each case, viz., 0·066, 0·066, and 0·061, and having a mean value of 0·064 grm., that being the total amount collected in one hour under the experimental conditions. The water I used was Vartry water, it being the water supply to my hospital, and when I used it unfiltered I employed the above number as a constant. As it would be necessary when I wished to get rid of epithelium to filter the portion of the bath water I took for analysis, I made three similar blank experiments, using filtered Vartry water, and obtained another constant, amounting to 0·0408 grm. of nitrogen, which I used in all such experiments. The method employed for estimating the nitrogen will be described later on. In the nine experiments in which I estimated the chlorides I took the precaution of finding the amounts of chlorides present in the Vartry water on that day, as I found the quantity of chlorides present in it liable to periodic variations.

I now commenced a series of experiments upon myself, with the assistance of my clinical clerk, Mr. Clune. One of these I shall describe:—I first took a sponge bath for the purpose of removing loose epithelial scales, as well as minute fibres from the underclothing, which I always found adhering to the skin, and having noted my pulse, respiration, bodily weight, and temperature, I entered under the canopy.* The coverings being carefully adjusted round my neck, the gas furnace was lighted, the air-pump and hydrometer adjusted, and the experiment continued for an hour, the time being carefully noted. Before leaving the canopy the pulse respiration and bodily temperature were again noted, also the mean temperature and point of saturation of the atmosphere within the canopy. On leaving the canopy I got into a bath containing twenty litres of Vartry water, acidulated with half an ounce of dilute hydrochloric acid of known strength. I took with me into the bath the linen sheet upon which I had lain whilst under the canopy, and with it I gently rubbed myself so as to remove any loose epithelial scales. On leaving the bath I again weighed myself, and in twenty minutes after I again noted my pulse, respiration, and bodily temperature. I caused the linen and india-rubber sheets, as well as the towers containing the dilute hydrochloric acid, to be washed in the water of the bath, and then brought a specimen of it to my laboratory for analysis. On two occasions I analysed the contents of the towers separately and got hardly a trace of ammonia with Nessler's test, proving, in these instances, at least, that free ammonia was not given off by the skin. The process of analysis of the water which I employed was briefly as follows:—I carefully measured 100 cub. centims. and poured it into a fractional distillation flask, which I altered to suit my purpose by shortening and bending the side tube upwards towards the mouth. I now took a porcelain dish, in which I placed a small quantity of pure sand, carefully cleansed by hydrochloric acid and subsequent washing with distilled water, and moistened it with a drop of strong, ammonia-free, sulphuric acid. Having placed the dish upon a water-bath, I inverted the flask into it, and, properly suspending it, carefully evaporated the water as it gradually flowed into the dish. When nearly dry I removed the sand from the dish and mixed it with soda-lime, in a small combustion tube, and proceeded to estimate the quantity of nitrogen contained in the residue in the manner referred to in a former paper.† Hence I calculated the quantity contained in the twenty litres, and from this I deducted my constant, thus ascertaining the total quantity of nitrogen excreted by the skin during the experiment. I have described an experiment in detail, as all the

* In my communication to the British Association, I gave the results of my observations on the effect of the hot air bath upon the rate of the pulse and respiration and on bodily temperature. I have since seen papers by Dr. Fleming, *op. cit.*, and Dr. C. Large ("Archiv Gén. de Méd.," Tom. i, 1880, p. 150), on the physiology of the Turkish bath, which go more fully into the immediate effects of artificially increased temperature upon the human body than I did, and I find that their results are confirmatory of my own.

† "Dublin Journal of Medical Science," vol. lix, No. 38, p. 81.

others were conducted in a similar manner. But in some instances I also filtered the aliquot part of the bath-water in order to get rid of epithelium, and then estimated the nitrogen in 100 cub. centims. of the filtrate; the result gave me the soluble nitrogen, *i.e.*, nitrogen present in some soluble compound, and the difference between this value and that afforded by the fluid containing suspended epithelium gave me the weight of the nitrogen present in the insoluble condition in the same portion of the bath-water. In the tabular statement I have noted the instances in which this additional estimation was made. I may here note that I examined the deposit from the water of the bath under the microscope, and found it to contain scarcely a trace of anything but epithelial scales.

Funke, by the only two completed analyses which he made, found in one case 0·198 grm. and in another 0·2935 grm. of soluble nitrogen excreted by the entire skin in one hour. But it must be remembered, as I have already pointed out, that his numbers are calculated values from imperfect data, and are not the results of direct determinations of the quantities excreted by the entire body in a given time.

In the accompanying table I give the results of twenty-five experiments upon six different individuals, viz., two healthy subjects and four hospital patients: cases which I considered suitable for treatment by the hot air bath. It will be seen that the greatest quantity of soluble nitrogen which I find to be excreted by the entire skin, in a case of Bright's disease (B) is 0·2392 grm. per hour. In experiment 1, case A (a healthy subject) we find that the quantity of soluble nitrogen excreted per hour is as low as 0·038 grm. And I find that the mean result of all my direct experiments, upon healthy and unhealthy subjects, gives 0·0824 grm. of soluble nitrogen collected from the entire skin in one hour. The difference between Funke's and my results may be in part due to the circumstance that my experiments were made upon the body in a state of rest, while Funke's were made under conditions of violent exercise, which I, accepting the views of Liebig, so strongly supported by the more recent experiments of Professor Flint,* believe to be always accompanied by waste of animal tissue and consequent increased excretion of nitrogen. With regard to Funke's estimation of the *possible* excretion of nitrogen per diem, amounting to as much as from 4·76 to 7·045 grms., I believe it to be excessive. He arrives at these results by multiplying the quantity obtained in an hour by twenty-four, necessarily assuming the constancy of the sweat secretion, which assumption is contradictory to the statement made in another part of his paper, to the effect that "in one or two hours the quantity of the supply begins to diminish, even though the temperature and movement remain un-

* "American Journ. Med. Science," vol. lxiii, n. s., p. 163.

altered, and falls to such a minimum that one can scarcely perceive the increase even during greater intervals of time."

I believe that under ordinary circumstances the excretion of nitrogen by the skin is very small indeed, even in cases of gout (Case D) and Bright's disease (Case B), in which I expected to find it present in larger amount. This being so I can now well understand how it was that Voit, Ranke, and Parkes, by their indirect methods came to the conclusion that there was *no* such excretion, yet I do not deny that under extraordinary circumstances, such as those mentioned by Leube,* Deininger,† Kaup and Jurgensen,‡ Taylor,§ Schottin,|| and others, crystals of urea may have been found upon the skin. However, with the exception of the case of Leube there does not appear sufficient evidence that adequate care was taken to ascertain that the crystals found were really those of urea and not of other salts, such as sodium chloride, crystals of which, as is well known, frequently simulate those of other bodies. I find that Leube notices this as an objection to the researches of former experimenters, and to obviate it he treated the mass removed from the skin with baryta-water and absolute alcohol in the usual manner, and so undoubtedly proved the presence of urea. Dr. Taylor seems also to have proved the presence of urea in the "saline mass" removed from the skin in a case of uræmic poisoning. Owing, I presume, to the smallness of the quantities obtained, none of the above-named experimenters give the quantity of the saline matter, nor the amount of urea found in it, with the exception of Kaup and Jurgensen, who state that they obtained 8·4 grms. from the shirt worn by a choleraic patient. My method of collecting the cutaneous excretion afforded me an easy means of ascertaining the quantity of sodium chloride excreted, and in the table will be found the quantities obtained in nine experiments. In five of these the amount excreted can be compared with that of soluble nitrogen, and it will be seen that the quantity of sodium chloride is comparatively great, the proportion to nitrogen, which is nearly constant, being as 10 : 1. In conclusion I would observe that though I found nitrogen to be excreted by the skin in all cases, yet the quantities are so small that I do not believe the cutaneous excretion can ever act vicariously towards the renal to any appreciable extent. I now submit this paper to the Society in the hope that some one having more leisure and more ample resources at his command may further prosecute the inquiry.

* "Deutsches Archiv für Klinische Medicin," Bd. vii, p. 1.

† *Id.*, Bd. vii, p. 587.

‡ *Id.*, Bd. vi, p. 55.

§ *Op. cit.*

|| Schottin, though he failed to find nitrogen in normal sweat as already mentioned, succeeded afterwards in doing so in a case of renal disease ("Schmidt's Jahrb.," Bd. 74, s. 9).

Reference to Case.	Remarks.	Number of experiment.	Period of year.	Duration of experiment.	Average temperature of bath.	Weight of body.	Age.	Average renal excretion of nitrogen during experimental period.	Cutaneous excretion.			
									Total nitrogen.	Soluble nitrogen. *	Insoluble nitrogen. †	Chlorine in terms of NaCl.
				h. m.	0° F.	Lbs.		Grms.				
A	Healthy subject	1	July	1 0	Not accurately observed, about 120°.	124	40	11·93	0·048	0·039	0·009	
		2	,,	1 0		..	..	..	0·112			
		3	,,	1 30		..	..	..	0·128			
		4	,,	1 0		..	..	..	0·096			
		5	,,	1 0		..	..	..	0·132			
		6	,,	1 0		..	..	..	0·128	0·091	0·037	
	a. Experiments 6 and 7, made on the same day.	7	,, *a*	0 45		..	..	..	0·080			
		8	,,	1 0		..	..	..	0·096	0·055	0·041	
	b. Experiments 8 and 9, made on the same day.	9	,, *b*	1 0		..	..	..	0·128	0·071	0·058	
B	Bright's disease, chronic, dropsical, sweating easily produced.	1	Aug.	1 0	124	155	43	..	0·336	0·2392	0·0968	
		2	,,	1 0	127	..	..	..	0·336	0·1792	0·4568	
		3	,,	1 0	118	..	..	..	0·116	0·052	0·064	
		4	,,	1 0	123	..	..	..	0·256	0·1192	0·1368	
C	Catarrh, urine loaded with lithates, otherwise healthy.	1	Jan.	1 10	131	161	21	19·3	0·128	0·039	0·089	
		2	,,	1 10	142	..	..	..	0·160			
		3	,,	1 0	125	..	..	..	0·176			
D	Gout, convalescent	1	Nov.	1 0	139	142	60	..	0·160	0·1292	0·0308	1·25
		2	,,	1 0	146	..	..	..	0·262	0·1672	0·0948	1·65
F	Sub-acute rheumatism, sweating difficult to produce.	1	Jan.	1 30	135	110	16	..	0·072	..	..	0·33
		2	,,	1 10	139	..	..	..	0·056	..	..	0·52
		3	,,	1 15	139	..	..	..	0·106	..	..	0·39
		4	,,	1 30	143	..	..	..	0·075	0·0472	0·0278	0·52
		5	,,	1 15	149	..	..	..	0·086	..	..	0·62
J	Acute nephritis	1	Dec.	1 15	120	162	40	6·92§	0·1425	0·125	0·017	1·26
		2	,,	1 25	135	..	..	..	0·125	0·096	0·029	1·00

* *i.e.*, nitrogen present in some soluble compound, *e.g.*, urea, &c. † *i.e.*, nitrogen present in some insoluble compound, *e.g.*, epithelium.

§ Less nitrogen as albumen.

February 23, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

THE BAKERIAN LECTURE on the "Chemical Theory of Gunpowder," was delivered by Professor H. DEBUS, Ph.D., F.R.S. Received February 8, 1882.

The following is an Abstract:—

1. Dr. Jebb* mentions a manuscript as existing at Oxford, entitled "Liber ignium ad comburendos hostes," by Marcus Græcus, probably written in the eighth century, wherein the preparation of gunpowder is accurately described, and Bellani reports that the English used cannon at the Battle of Crecy. Gunpowder, therefore, has been known more than a thousand years, and its use for the purposes of war more than five hundred, nevertheless, no chemical theory of the combustion of gunpowder has hitherto been proposed which will enable us to calculate the quantity of each of the chief products of combustion from the known composition of a given weight of powder, or the amount of heat generated during its metamorphosis. A theory which can solve these problems I have the honour to submit in the present paper to the Royal Society.

2. The constituents of gunpowder—saltpetre, charcoal, and sulphur—are transformed during combustion into the following products:—Potassic carbonate, potassic sulphate, potassic disulphide, potassic sulphocyanate, carbonic acid, carbonic oxide, nitrogen, sulphuretted hydrogen, marsh-gas, ammonia, hydrogen, and water.

The hydrogen compounds—sulphuretted hydrogen, ammonia, and marsh-gas, the free hydrogen and potassic sulphocyanate—do not, as a rule, amount together to more than about two per cent. of the weight of the powder from which they have been produced; and as their formation is not the direct result of the reactions which cause the explosion of the powder, they are regarded as secondary products and not considered in a discussion of the chemical metamorphosis of gunpowder.

Besides the potassium salts mentioned, potassic hyposulphite has been found as one of the constituents of the solid residue left by powder after its explosion. According to experiments by the author, which have been confirmed by Noble and Abel, this salt is formed in considerable quantities from potassic sulphide during the analysis of

* Poggendorff, "Geschichte der Physik," 87.

the residues according to Bunsen and Schischkoff's method; and as it is decomposed at 225° C., it cannot be considered as one of the chief products of the combustion of gunpowder.

3. With regard to the products, potassic carbonate, potassic sulphate, potassic disulphide, carbonic acid, carbonic oxide, and nitrogen, the following problems have to be solved :—

(*a.*) To determine the reactions which cause the formation of these substances and the order in which they succeed each other, and to represent the *complete* combustion of gunpowder by one chemical equation.

(*b.*) To calculate from the known composition of a given weight of powder the volume of gas and the amount of heat generated during its combustion, and to ascertain the relative energies of powders of different composition.

The solution of each of these problems is described in the paper.

4. Noble and Abel* describe the quantitative relations of the products of combustion of a given weight of powder of known composition in the following words :—

"(*a.*) The proportions in which the several constituents of solid powder residue are formed are quite as much affected by slight accidental variations in the conditions which attend the explosion of one and the same powder in different experiments, as by decided differences in the composition as well as in the size of grain of different powders.

"(*b.*) The variations in the composition of the products of explosion furnished in close chambers by one and the same powder under different conditions, as regards pressure, and by two powders of similar composition under the same conditions, as regards pressure, are so considerable, that no value whatever can be attached to any attempt to give a general chemical expression to the metamorphosis of gunpowder of normal composition.

"(*c.*) Any attempt to express, even in a comparatively complicated chemical equation, the nature of the metamorphosis which a gunpowder of average composition may be considered to undergo, when exploded in a confined space, would therefore only be calculated to convey an erroneous impression as to the simplicity or the definite nature of the chemical results and their uniformity under different conditions, while it would, in reality, possess no important bearing upon an elucidation of the theory of explosion of gunpowder.†

"(*d.*) Very small-grain powder, such as F.G. and R.F.G., furnish decidedly smaller proportions of gaseous products than a large-grain powder, R.L.G.: while the latter again furnishes somewhat smaller proportions than a still larger powder, P, though the difference between the gaseous products of these two powders is comparatively inconsiderable."

* "Phil. Trans.," clxv (1875), p. 137. † *Ibid.*, p. 85.

Noble and Abel exploded successively portions of powder of the same description in their apparatus, and found considerable fluctuations in the relative quantities of the products of explosion in different experiments. These fluctuations they do not explain, but state that "*slight accidental variations in the conditions which attend the explosion*," have as much influence on the relative quantities of the constituents of the solid powder residue as decided differences in the composition of the different powders. And as the exact nature of these "slight accidental variations in the conditions which attend the explosion" is not known, they conclude that the metamorphosis cannot be represented by a chemical equation.

The author of this abstract has described in the paper the causes of the variations in the relative quantities of the products of explosion, and has explained the experimental results of Messrs. Noble and Abel. And further, he has been able, with this knowledge, to represent the chemical metamorphosis of the English Service powders by an equation.

5. Noble and Abel assume that the samples of fine-grain and pebble powders used in their numerous experiments were, respectively, of the same composition, and that the samples of R.L.G. powder employed in their earlier experiments, had the composition given under "I," and those used in the later experiments that given under "II" in the table below.

The composition of the same description of powder is, however, not constant.

I requested the late Mr. Wills to analyse pebble and R.L.G. powders from Waltham Abbey, and the results obtained by him, together with those of Noble and Abel, are given in the following table :—

	R.L.G.			Pebble powder.	
	Noble and Abel.		Wills.	Noble and Abel.	Wills.
	I.	II.			
Saltpetre	74·95	74·43	75·10	74·67	74·26
Sulphur	10·27	10·09	8·96	10·07	9·51
Charcoal—					
Carbon	10·86	12·40	12·09	12·12	11·58
Hydrogen	0·42	0·40	0·54	0·42	0·51
Oxygen	1·99	1·27	2·12	1·45	2·55
Ash	0·25	0·21	0·20	0·23	0·33
Water	1·11	1·05	0·85	0·95	0·76

The samples analysed by Noble and Abel were taken out of the *same barrel*, the one from the upper, the other from the lower parts. These two samples showed a difference of no less than 1·54 per cent. of the weight of the powder in the amount of carbon they contain, or the weight of carbon is by one-seventh greater in the second than in the first sample. Mr. Wills found 1·31 per cent. of sulphur less than Noble and Abel in the same description of powder. Such differences in the composition of samples of powder of the same nature, together with the usual errors attaching to complicated and difficult analytical operations, are almost sufficient to explain the variations in the proportions of the products of the combustion of gunpowder, as found by Messrs. Noble and Abel, without requiring a theory like the one proposed by M. Berthelot for that purpose.

6. Noble and Abel analysed the products of explosion by means of Bunsen and Schischkoff's method. The author has proved that by the treatment of the solid powder residue according to this method a portion of the potassic sulphide is converted into potassic hyposulphite, and under certain conditions into potassic sulphate. The quantities of the two salts so produced vary in different experiments. Hence, the fluctuations observed by Noble and Abel in the relative quantities of potassic sulphide, potassic sulphate, and potassic hyposulphite are partly, if not entirely, due to the method of analysis. Potassic hyposulphite is decomposed at temperatures above 225°; from this fact, as well as from a comparison of the oxygen in the original powder with that of the products of explosion, it follows that the potassic hyposulphite found in powder residues must be regarded as the product of the analytical method.

7. It is well known that the higher sulphides of potassium attack metals with great energy at a white heat. Noble and Abel exploded their powders in a hermetically closed steel cylinder at high pressures, and the products remained after explosion from one to two minutes in a fluid condition at a white heat in contact with the iron of the apparatus. These products contain potassic disulphide. The description given by Noble and Abel of their solid powder residues indicates that they contain ferrous sulphide. The absorption of a portion of the sulphur by the iron will increase the amount of potassic carbonate and diminish the quantities of potassic sulphate and disulphide. The quantity of sulphur so uniting with iron depends on pressure, time of cooling, and other conditions, and will vary in different experiments. We have then in the formation of ferrous sulphide another cause of the fluctuation in the quantities of the products of explosion observed by Messrs. Noble and Abel.

8. It follows from the statements given under Nos. 5, 6, and 7, that there is no reason to assume that the chemical metamorphosis of gunpowder cannot be represented by an equation.

9. Noble and Abel calculate the total weight of the solid residue,

which a given weight of powder can produce by its explosion, from the composition of *a portion* of the residue and the composition of the powder. They assume that the portions of powder of the same description used in different experiments, were of the same composition. This is, according to the statements under No. 5, not the case. The calculated quantities of gas and solid residue which a given weight of powder can produce, will, in consequence, be affected by certain errors. These errors compensate each other if the mean of many experiments is taken.

10. Portions of powder taken from different parts of the same barrel show, according to Noble and Abel's analyses, greater differences in their composition than samples of different descriptions manufactured at Waltham Abbey, pebble, rifle fine-grain, rifle large-grain, and fine-grain powder; hence, we are justified in taking the mean of the analyses of these powders, and expressing thereby the composition of the English Service powder. The mean of the analyses of Noble and Abel, and Wills, can be represented by the symbols—

$$16KNO_3 + 21{\cdot}18C + 6{\cdot}63S,$$

if hydrogen, oxygen, and ash of the charcoal, and the hygroscopic moisture of the powder are neglected.

11. From evidence described in the paper it follows, with a high degree of probability, that during the combustion of gunpowder potassic disulphide, and not monosulphide, as is usually assumed, is formed.

12. If the errors arising from the analytical method are corrected as explained in the paper, if allowance is made for the sulphur which has united with the iron of the apparatus, and, finally, if, for the reasons adduced under No. 9, the mean is taken of the thirty-one analyses published by Noble and Abel, then the explosion of the powders of Waltham Abbey, as conducted by Noble and Abel in a confined space, can be represented very nearly, if not quite accurately, by the following equation:—

$$16KNO_3 + 21C + 5S = 5K_2CO_3 + K_2SO_4 + 2K_2S_2 + 13CO_2 + 3CO + 8N_2 \quad . \; . \; . \; . \; . \; . \; . \quad (2).$$

1·63 atoms of the sulphur contained in the powder have united partly with hydrogen and formed sulphuretted hydrogen, partly with iron and produced ferrous sulphide. The entire amount of the oxygen contained in the charcoal is eliminated with hydrogen as water, the rest of the hydrogen either remains free or produces methane with carbon and ammonia with nitrogen. The composition of the powder, calculated from the mean composition of the products of explosion of thirty-one experiments, can be represented by the symbols

$$16KNO_3 + 21{\cdot}35C + 6{\cdot}62S,$$

which are almost identical with

$$16KNO_3+21{\cdot}18C+6{\cdot}63S,$$

representing the mean composition of the powders found by direct analysis.

13. An increase of pressure during combustion appears to diminish the amount of carbonic oxide, and, in consequence, according to equation 8, to increase the quantities of potassic carbonate, potassic disulphide, and carbonic acid. These fluctuations in the quantities of the products of combustion are, however, *very small*, and may be neglected without serious error.

14. Craig had asserted that the nature of the products of explosion of gunpowder depended on the pressure developed during combustion. Karolyi, in order to test this assertion, made experiments with Austrian Service powder, and arrived at the conclusion that pressure had no influence on the quality or quantity of the products furnished by these powders.

The experimental results of Karolyi, and the differences between these results and those obtained by Noble and Abel, have enabled the author to develop a chemical theory of gunpowder competent to explain the observations of Bunsen and Schischkoff, Linck, Karolyi, Noble, and Abel, and other investigators, and which is in harmony with the thermochemical relations of the reacting substances.

According to this theory the combustion of gunpowder takes place in two stages, one succeeding the other. The reactions of the first stage cause the explosion of the powder. *Gunpowders which differ considerably in their composition* are transformed during the first stage according to the equation

$$10KNO_3+8C+3S=2K_2CO_3+3K_2SO_4+6CO_2+5N_2 \quad . \quad . \quad (3),$$

but as it is probable that at the same time some carbonic oxide is produced, the following would more correctly represent the reactions:—

$$16KNO_3+13C+5S=3K_2CO_3+5K_2SO_4+9CO_2+CO+8N_2 \quad . \quad (4),$$

The constituents of the powder, and those of the products of combustion are, according to equation 4, nearly in the same ratios as they are according to 3.

During the first stage of the combustion potassic disulphide is not formed.

The oxygen of the potassic carbonate, potassic sulphate, and the carbonic acid, as represented by equation 3, stand to each other in the most simple possible ratios, if these substances are to be produced by the combustion of a mixture of saltpetre, carbon, and sulphur. In other words, equation 3 represents the most simple distribution of the oxygen of the decomposed saltpetre amongst the products of combustion produced during the first stage. And because these products are, according to equation 4, nearly in the same relative proportions as they are according to 3, it follows that the distribution of the oxygen of the saltpetre between potassic sulphate, potassic carbonate, and carbonic acid, as required by equation 4, corresponds nearly to the most simple ratios which can exist under the conditions of the experiments.

The oxygen of the potassic carbonate stands to the oxygen of the potassic sulphate and of the carbonic acid, according to equation 3, as

$$1 : 2 : 2.$$

If a mixture of saltpetre, carbon, and sulphur shall produce, by its combustion, the greatest possible amount of heat, and if at the same time the products—potassic sulphate, potassic carbonate, and carbonic acid—shall be formed in such proportions that the heat of formation of one shall stand to the heat produced by each of the other two in the most simple ratio possible, then the combustion must take place according to equation 4.

The heat developed by the formation of potassic carbonate stands to that furnished by potassic sulphate and carbonic acid respectively as

$$1 : 2{\cdot}05,$$

and

$$1 : 1{\cdot}04.$$

if the powder is transformed according to equation 4.

The relations between the quantities of oxygen in the chief products of combustion and those of the heat produced by their formation are, from a theoretical point of view, of the greatest interest.

15. Gunpowder, as a rule, contains more carbon and sulphur than is required by equations 3 and 4.

The carbon left free at the end of the first stage of the combustion now acts on the potassic sulphate, formed during this stage, according to the equation

$$4K_2SO_4+7C=2K_2CO_3+2K_2S_2+5CO_2 \quad . \quad . \quad . \quad . \quad (6),$$

and the free sulphur upon potassic carbonate according to

$$4K_2CO_3+7S=K_2SO_4+3K_2S_2+4CO_2 \quad . \quad . \quad . \quad . \quad (5),$$

and some of the free carbon reduces carbonic acid to oxide.

These reactions constitute the second stage of the combustion of gunpowder; they are endothermic, heat is not evolved but is rendered latent; they are not of an explosive nature, and, in practice, are probably seldom complete. During the second stage of the combustion the temperature of the products of explosion is diminished and the volume of the gas is increased.

16. The quantitative relations between the constituents of gunpowder and the chief products of combustion at the end of the second stage can be expressed by one equation.

If x, y, and z be positive numbers and a represents how many molecules of carbonic oxide are formed by the complete combustion of a weight of powder containing x molecules of saltpetre, y atoms of carbon, and z atoms of sulphur, we have

$$\begin{aligned} xKNO_3+yC+zS= &\tfrac{1}{28}[4x+8y-16z-4a](K_2CO_3) \\ &+\tfrac{1}{28}[20x-16y+4z+8a](K_2SO_4) \\ &+\tfrac{1}{28}[-10x+8y+12z-4a](K_2S_2) \\ &+\tfrac{1}{28}[-4x+20y+16z-24a](CO_2) \\ &+aCO \\ &+\tfrac{1}{2}xN_2 \ldots\ldots\ldots\ldots \quad (8), \end{aligned}$$

as the general equation of the complete combustion of gunpowder.

By means of this equation the chief products of combustion—potassic carbonate, potassic sulphate, potassic disulphide, and carbonic acid—can be calculated from that portion of a given weight of powder which transforms itself into these products.

The correctness of the equation is proved by the agreement of the calculated numbers with those observed by Bunsen and Schischkoff, Linck, and Karolyi in their experiments on the explosion of gunpowder, and also with the corrected mean numbers derived from Noble and Abel's investigation.

17. The total volume of gas developed by the combustion of a given weight of powder, if calculated according to equation (8), is not affected to more than from one to two per cent. if we put $a=0$, and in doing so we gain a considerable simplification of the equation. If V represents the volume of gas evolved by the combustion of a quantity of powder containing 16 molecules of saltpetre, y atoms of carbon, and z atoms of sulphur, and W the units of heat developed by the same weight of powder, we have, on the assumption that $a=0$,

$$V=\frac{160+20y+16z}{14} \ldots\ldots\ldots \quad (9),$$

$$W=1000[1827{\cdot}154-16{\cdot}925y-8{\cdot}788z] \ldots \quad (10).$$

The volume of gas becomes *greater*, and the amount of heat *diminishes*, when y and z are increased, and *vice versâ*.

Quantities of saltpetre, carbon, and sulphur represented by the symbols

$$16KNO_3+8C+8S$$

produce the greatest amount of heat and smallest amount of gas, and such as correspond to—

$$16KNO_3+24C+16S,$$

the largest volume of gas and the smallest quantity of heat, if the mixtures are considered which can transform themselves during combustion according to equation (8), in which a is put $=0$.

(8.) The product of (9) and (10) divided by 2×1000,

$$\frac{V\times W}{2000}=10440\cdot88-12\cdot09y^2+1208\cdot39y-15\cdot95yz+993\cdot867z-5\cdot022z^2$$
$$=E \quad \ldots \quad (11),$$

will assume different values for powders of different composition. The energy of a mixture of saltpetre, carbon, and sulphur will be, *cæteris paribus*, proportional to the volume of gas, and also to the amount of heat produced during its combustion. Hence, the product of the two, E, may be used, according to the proposal of M. Berthelot, as a measure of the relative energies of powders of different composition.

(9.) If in equation (8) x is put $=16$, and $a=0$, we obtain:

$$\begin{aligned}16(KNO_3)+yC+zS= \; & \tfrac{1}{28}[64+8y-16z](K_2CO_3)\\ & +\tfrac{1}{28}[320-16y+4z](K_2SO_4)\\ & +\tfrac{1}{28}[-160+8y+12z](K_2S_2)\\ & +\tfrac{1}{28}[-64+20y+16z](CO_2)\\ & +8N_2 \quad \ldots \quad (13),\end{aligned}$$

and from this, if the coefficients of the potassic carbonate, potassic sulphate, and potassic disulphide are put $=0$, the equations:

$$64+8y-16z=0 \quad \ldots \quad (14),$$
$$320-16y+4z=0 \quad \ldots \quad (15),$$
$$-160+8y+12z=0 \quad \ldots \quad (16).$$

These equations represent in a plane three sides of a triangle. The co-ordinates of points within this triangle represent quantities of carbon and sulphur, which can, with 16 molecules of saltpetre transform themselves according to equation (13), whereas the co-ordinates of points outside this triangle indicate mixtures which cannot do so, such mixtures containing either too much or too little of carbon or sulphur.

The co-ordinates of points on the sides of the triangle represent mixtures which will burn with the production of two, and those of the points of intersection of two sides with formation of only one potassium salt.

The two sides represented by equations (14) and (16) intersect in point $y=8$, and $z=8$. These values introduced into (13) give:

$$16KNO_3++8C+8S=8K_2SO_4+8CO_2+8N_2.$$

In the same manner we obtain for the point of intersection corresponding to equations (15) and (16):

$$16KNO_3+20C=8K_2CO_3+12CO_2+8N_2,$$

and finally, the sides whose equations are (14) and (15), intersect in point $y=24$ and $z=16$, hence

$$16KNO_3+24C+16S=8K_2S_2+24CO_2+8N_2.$$

The geometrical construction of the co-efficients of equation (13) possesses the great advantage of indicating by the co-ordinates of the points of a triangle the composition of the infinite number of mixtures of saltpetre, carbon, and sulphur which can transform themselves during combustion according to equation (13), and enables us to deduce *geometrically*, as is shown in the paper, the qualitative nature and the quantitative relations of the products of combustion, as well as the volume of gas and the amount of heat developed by each mixture.

(20.) It is proved in the paper that the composition of a powder which can transform itself during combustion according to equation (13), and for which E in equation (11) shall be a maximum, is indicated by the co-ordinates of the point of intersection of the sides of the triangle represented by the equations (14) and (15).

If, therefore, such quantities of powders of different composition are compared, which contain 16 molecules of saltpetre, the one composed of $16KNO_3+24C+16S$ will possess the greatest energy.

(21.) If E is calculated for *equal weights* of two powders of different composition, the difference of the values of E is found to be *very small*, if the powders contain from 21 to 24 atoms of carbon, and from 8 to 16 atoms of sulphur for every 16 molecules of saltpetre. Equal weights of the two mixtures

$$16KNO_3+22C+8S,$$

and

$$16KNO_3+24C+16S,$$

give for E [equation (11)] the values 16·84 and 16·95 respectively. If, therefore, a mixture of saltpetre, carbon, and sulphur is required, which shall possess the greatest or nearly the greatest amount of energy, and at the same time contain the smallest amount of carbon and sulphur compatible with this condition, theory would point to the mixture

$$16KNO_3+22C+8S.$$

The gunpowders of most nations fluctuate about

$$16KNO_3+21{\cdot}2C+6{\cdot}8S,$$

which numbers are very near those required by theory.

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Stoppani (A.) e G. Negri. Carattere Marino dei Grandi Anfiteatri Morenici dell' Alta Italia. 8vo. *Milano* 1878. The Author.

Wernicke (Hermann) Die Welt-Erklärung. 8vo. *Philadelphia* 1881. The Author.

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March 2, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

H.R.H. the Prince of Wales was admitted into the Society.

In pursuance of the Statutes, the names of Candidates recommended for election into the Society were read, as follows:—

Allman, George Johnston, LL.D.
Ball, Professor Valentine, M.A.
Baxendell, Joseph, F.R.A.S.
Bell, James, F.I.C.
Brady, Professor George Stewardson, M.D., F.L.S.
Braidwood, Peter Murray, M.D.
Browne, James Crichton, M.D., LL.D., F.R.S.E.
Buchanan, George, M.D., F.R.C.P.
Clarke, Charles Baron, M.A., F.L.S., F.G.S.
Creak, Ettrick William, Staff-Commander R.N.
Cunningham, Allan Joseph Champneys, Major R E.
Curtis, Arthur Hill, A.M., LL.D., D.Sc.
Dallas, William Sweetland, F.L.S.
Darwin, Francis, M.A., M.B., F.L.S.
Day, Francis.
Dittmar, Professor William, F.C.S., F.R.S.E.
Dobson, George Edward, M.A., M.B., F.L.S.
Flight, Walter, D.Sc., F.G.S.
Foster, Professor Balthazar Walter, F.R.C.P.
Gaskell, Walter Holbrook, M.A., M.D.
Glazebrook, Richard Tetley, M.A.
Godman, Frederic Du Cane, F.L.S., F.G.S.
Goodeve, Professor Thomas Minchin, M.A.
Groves, Charles Edward, F.C.S.
Grubb, Howard, F.R.A.S.
Hartley, Professor Walter Noel, F.R.S.E.
Hutchinson, Jonathan, F.R.C.S.
Ley, Rev. W. Clement, M.A.
Liversidge, Professor Archibald, F.G.S., F.C.S., F.L.S.
Malet, Professor John, M.A.
Meldola, Raphael, F.R.A.S.
Miller, Francis Bowyer, F.C.S.
Niven, William Davidson, M.A.
Ord, William Miller, M.D., F.L.S., F.R.C.P.
Palgrave, Robert Henry Inglis, F.S.S.
Pattison, Samuel Rowles, F.G.S.
Pritchard, Urban, M.D., F.R.C.S.
Ransome, Arthur, M.A., M.D.
Ranyard, Arthur Cowper, F.R.A.S.
Rawlinson, Robert, C.B., M.I.C.E.
Reinold, William Arnold, M.A.
Tidy, Charles Meymott, M.B., F.C.S.
Topley, William, F.G.S.
Trimen, Roland, F.L.S., F.Z.S.

Venn, John, M.A.
Walker, John James, M.A.
Warrington, Robert, F.C.S.
Watson, Professor Morrison, M.D.
Weldon, Walter, F.C.S., F.R.S.E.
Williams, Charles Theodore, M.A., M.D., F.R.C.P.
Wright, Professor Edward Perceval, M.A., M.D., F.L.S.

The following Papers were read:—

I. "A Contribution to the Pathology of the Epidemic known as the 'Salmon Disease.'" By Professor T. H. Huxley, LL.D., F.R.S. Received February 21, 1882.

For some years, an epidemic disease, followed by a very large number of deaths, has been observed to prevail among the salmon of certain Scottish and British rivers, from the Tay,* on the north, as far as the Conway on the south.

The first obvious symptom of the malady is the appearance of one or more greyish patches upon the skin of parts of the body which are not covered with scales, such as the top and sides of the head, the adipose fin, and the soft skin at the bases of the other fins.

Such a patch, when it first attracts attention, may be as big as a sixpence. It is nearly circular, with a well defined margin and a somewhat raised softer centre, from which faint ridges radiate towards the circumference. It is important to observe that a single small patch of this kind may be seen on the skin of a fish which, in all other respects, is perfectly healthy, and when there is no indication that the skin has ever been bruised or abraded in the place occupied by the patch. The patch, once formed, rapidly increases in size and becomes confluent with any other patches which may have appeared in its neighbourhood. The marginal area, as it extends over the adjacent healthy skin, retains its characters; but the central part undergoes an important change. It takes on the consistency of wet paper, and can be lifted up in soft flakes, as if it were a slough, from the surface of the derma or true skin, which it covers. In fact, it is obvious that this papyraceous substance has taken the place of the epidermis, so that the sensitive and vascular true skin is deprived of its natural protection. As the patch spreads, the true skin beneath the central papyraceous slough ulcerates and an open bleeding sore is formed, which may extend down to the bone, while it passes outwards into burrowing sinuses.

When the disease has reached this stage it obviously causes great irritation. The fish dash about and rub themselves against stones, and thus, in all probability, aggravate the evils under which they suffer.

* Within the last few days I have received specimens of diseased fish from the North Esk. (March 8.)

One vast open sore may cover the top of the head from the snout to the nape, and may extend over the gill covers. The edges of the fins become ragged; and, sometimes, the skin which invests them is so completely frayed away that the fin-rays stand out separately.

Although the affection of the skin appears, usually, if not invariably, to commence in the scaleless parts of the body, it does not stop there, but gradually spreads over the whole of the back and sides of the fish, though I have not yet seen a specimen in which it covered the whole ventral surface. The disease extends into the mouth, especially affecting the delicate valvular membrane attached to the inner sides of the upper and the lower jaws. It is said to attack the gills, but there has been no sign of it on these organs in any fish which I have had the opportunity of examining.

Fish which succumb to the disease become weak and sluggish, seeking the shallows near the banks of the river, where they finally die.

The flesh of a salmon affected by this disease presents no difference in texture or colour from that of a healthy fish; and those who have made the experiment declare that the flavour is just as good in the former case as in the latter. So far as my observations have gone the viscera may be perfectly healthy in the most extensively diseased fish; and there is no abnormal appearance in the blood.

It is known that a disease similar to that described is occasionally prevalent among salmon in North America and in Siberia; and I do not see any ground for the supposition that it is a novelty in British rivers. But public attention was first directed to it in consequence of its ravages in the Solway district a few years ago; and, in 1879, a Commission was appointed by Sir Richard Cross, then Home Secretary, to inquire into the subject.

The evidence taken by the Commissioners* leaves no room for doubt that the malady is to be assigned to the large and constantly increasing class of diseases which are caused by parasitic organisms. It is a contagious and infectious disease of the same order as ringworm in the human subject, muscardine among silkworms, or the potato disease among plants; and, like them, is the work of a minute fungus. In fact, the *Saprolegnia* which is the cause of the salmon disease is an organism in all respects very closely allied to the *Peronospora*, which is the cause of the potato disease.

It is a very curious circumstance, however, that while the *Peronosporæ* are always parasites—that is to say, depend altogether upon

* "Report on the Disease which has recently prevailed among the Salmon in the Tweed, Eden, and other Rivers in England and Scotland." By Messrs. Buckland, Walpole, and Young, 1880.

See also the three valuable communications to the "Proceedings of the Royal Society of Edinburgh," made by the late Mr. A. B. Stirling in 1878–79.

living plants for their support—the *Saprolegniæ* are essentially saprophytes; that is to say, they ordinarily derive their nourishment from dead animal and vegetable matters, and are only occasionally parasites upon living organisms. In this respect they resemble the *Bacteria*, if the results of recent researches, which tend to show that pathogenic bacteria are mere modifications of saprogenic forms, are to be accepted.

As I have said, I do not think that the evidence laid before the Commission of 1879 can leave any doubt as to the causation of the salmon disease on the minds of those who are acquainted with the history of the analogous diseases in other animals and in plants. Nevertheless, this evidence, valuable as it is, suggests more questions than it answers, and in November, 1881, hearing that the disease had broken out in the Conway, I addressed myself to the attempt to answer some of these.

It was already known that when the papyraceous slough-like substance which coats the skin of a diseased salmon is subjected to microscopic examination, it is found to be a *mycelium*, or fungus-turf, composed of a felt-work of fine tubular filaments or *hyphæ*, many of which are terminated by elongated oval enlargements, or *zoosporangia*. Within these the protoplasm breaks up into numerous spheroidal particles, each less than $\frac{1}{2000}$ of an inch in diameter. These, the *zoospores*, are set free through an opening formed at the apex of the zoosporangium, and become actively or passively dispersed through the surrounding water. Herein lies the source of the contagiousness or infectiousness of the disease. For any one of these zoospores, reaching a part of the healthy skin of the same or of another salmon, germinates and soon gives rise to a mycelium similar to that from which it started.

But I could find no satisfactory information as to the manner in which the fungus enters the skin, how far it penetrates, the exact nature of the mischief which it does, or what ultimately becomes of it; nor was the identity of the pathogenic *Saprolegnia* of the salmon with that of any known form of saprogenic *Saprolegnia* demonstrated. It appeared to me, however, to be useless to attempt to deal with the disease until some of these important elements of the question were determined.

To this end, in the first place, I made a careful examination of the minute structure of both the healthy and diseased skin, properly hardened and cut into thin sections; and, in the second place, I tried some experiments on the transplantation of the *Saprolegnia* of the living salmon to dead animal bodies. Perhaps it will conduce to intelligibility if I narrate the results of the latter observations first.

The body of a recently killed common house-fly was gently rubbed two or three times over the surface of a patch of the diseased skin of a salmon and was then placed in a vessel of water, on the surface of which it floated, in consequence of the large quantity of air which a fly's body contains. In the course of forty-eight hours, or thereabouts, innumerable white cottony filaments made their appearance, set close side by side, and radiated from the body of the fly in all directions. As these filaments had approximately the same length, the fly's body thus became inclosed in a thick white spheroidal shroud, having a diameter of as much as half an inch. As the filaments are specifically heavier than water, they gradually overcome the buoyancy of the air contained in the tracheæ of the fly, and the whole mass sinks to the bottom of the vessel. The filaments are very short when they are first discernible, and usually make their appearance where the integument of the fly is softest, as between the head and thorax, upon the proboscis, and between the rings of the abdomen. These filaments, in their size, their structure, and the manner in which they give rise to zoosporangia and zoospores are precisely similar to the hyphæ of the salmon fungus; and the characters of the one, as of the other, prove that the fungus is a *Saprolegnia* and not an *Achlya.* Moreover, it is easy to obtain evidence that the body of the fly has become infected by spores swept off by its surface when it was rubbed over the diseased salmon skin. These spores have in fact germinated, and their hyphæ have perforated the cuticle of the fly, notwithstanding its comparative density, and have then ramified outwards and inwards, growing at the expense of the nourishment supplied by the tissues of the fly.

This experiment, which has been repeated with all needful checks, proves that the pathogenic *Saprolegnia* of the living salmon may become an ordinary saprogenic *Saprolegnia;* and, *per contra*, that the latter may give rise to the former; and they lead to the important practical conclusion that the cause of salmon disease may exist in all waters in which dead insects, infested with *Saprolegniæ*, are met with; that is to say, probably in all the fresh waters of these islands, at one time or another.

On the other hand, *Saprolegnia* has never been observed on decaying bodies in salt water, and there is every reason to believe that, as a saprophyte, it is confined to fresh waters.*

Thus it becomes, to say the least, a highly probable conclusion that we must look for the origin of the disease to the *Saprolegniæ* which infest dead organic bodies in our fresh waters. Neither pollution, drought, nor overstocking will produce the disease if the *Saprolegnia* is absent. The most these conditions can do is to favour the development or the diffusion of the *materies morbi* where the *Saprolegnia* already exists.

Having infected dead flies with the salmon *Saprolegnia*, once from

* So far as I know, there is only one case on record of the appearance of a fungus on a fish in salt water, and in this case it is not certain that the fungus was a *Saprolegnia.*

Conway and once from Tweed fish,* I was enabled to propagate it from these flies to other flies, and, in this manner, to set up a sort of garden of *Saprolegniæ*. And having got thus far, I fancied it would be an easy task to determine the exact species of the *Saprolegnia* with which I was dealing, from the abundant data furnished by the works of Pringsheim, De Bary, and others, who have so fully studied these plants when cultivated on the same materials. For this purpose, it was necessary to obtain the oosporangia; and, in ordinary course, these should have made their appearance on my *Saprolegniæ* in five or six days. Unfortunately, in the course of cultivations continued over two months, nothing of the kind has taken place. Zoosporangia have abounded in the ordinary form and also in that known as "dictyosporangium," but, in no instance, have any oosporangia appeared. After a few days of vigorous growth, the zoosporangia become scanty, and the fungus takes on a torulose form, segments of the hyphæ becoming swollen and then detached as independent "gemmæ," which may germinate. Sometimes the gemmæ are spheroidal and terminal, and closely simulate oosporangia.

Although, therefore, I have very little doubt that the *Saprolegnia* of the salmon is one of the forms of the "*S. ferax* group" of Pringsheim and De Bary, I have, at present, no proof of the fact.

Another very curious and unexpected peculiarity of the salmon *Saprolegnia*, both on the fish and when transmitted to flies, so far as my observations have hitherto gone, is that locomotive ciliated zoospores do not occur. I once saw one which exhibited a very slight motion for a few minutes after it left the zoosporangium; but although thousands must have passed under my notice, with the exception to which I have referred, they have always been perfectly quiescent and not unfrequently in different stages of germination. Whether the season of the year, or the conditions under which my saprolegnised flies were placed, have anything to do with the non-appearance of oosporangia and of locomotive zoospores in them I cannot say. But it is certain that the *Saprolegnia ferax* which commonly appears upon dead flies and other insects normally develops both oosporangia and locomotive zoospores in abundance.

From such notices by other observers as I can gather, oosporangia appear to be of very rare occurrence in the *Saprolegnia* of the salmon itself. Mr. Stirling mentions that he has met with them only four times. With respect to locomotive zoospores, I can find no positive evidence that they have been regularly, or even frequently, observed in the salmon *Saprolegnia*. But these points require careful investigation on freshly taken diseased fish.

Whether the zoospores are actively locomotive or not, they are quite

* And since this paper was read once more from the North Esk fish. (March 8, 1882.)

free when they emerge from the zoosporangia; and, from their extreme minuteness, they must be readily carried away and diffused through the surrounding water. Hence, a salmon entering a stream inhabited by the *Saprolegnia* will be exposed to the chance of coming into contact with *Saprolegnia* spores; and the probability of infection, other things being alike, will be in proportion to the quantity of the growing *Saprolegnia*, and the vigour with which the process of spore-formation is carried on. At a very moderate estimate, a single fly may bear 1,000 fruiting hyphæ; and if each sporangium contains twenty zoospores, and runs through the whole course of its development in twelve hours, the result will be the production of 40,000 zoospores in a day, which is more than enough to furnish one zoospore to the cubic inch of twenty cubic feet of water. Even if we halve this rate of production, it is easy to see that the *Saprolegnia* on a single fly might furnish spores enough to render such a small shallow stream as salmon often ascend for spawning purposes, dangerous for several days. But a large fully diseased salmon may have as much as two square feet of its skin thickly covered with *Saprolegnia*. If we allow only 1,000 fruiting hyphæ for every square inch, we shall have 288,000 for the whole surface, which, at the same rate as before, gives over 10,000,000 spores for a day's production, or enough to provide a spore to every cubic foot of a mass of water 100 feet wide and 5 feet deep and four miles long. Forty such diseased salmon might furnish one spore to the gallon for all the water of the Thames (380,000,000 gallons per diem) which flows over Teddington Weir. But two thousand diseased salmon have been taken out of a single comparatively insignificant river in the course of a season.

It will be understood that the above numerical estimate of the productivity of *Saprolegnia*, has been adopted merely for the sake of illustration; that I do not intend to suggest that the zoospores are evenly distributed through the water into which they are discharged by the zoosporangia; and that allowance must be made for the very short life of those zoospores which do not speedily reach an appropriate nidus. Nevertheless, the conclusion remains arithmetically certain that every diseased salmon adds immensely to the chances of infection of those which are not diseased; and thus, the policy of extirpating every diseased fish as soon as possible, has ample justification. But, in practice, the attempt to stamp out the disease in this fashion would be so costly that it may be a question whether it is not better to put up with the loss caused by the malady.

There are many practical difficulties in the way of directly observing the manner in which the zoospores effect their entrance into the skin of the fish; but, on comparing the structure of the healthy integument with that of the diseased patches, the manner of the operation can readily be divined. The skin of the head of a salmon, for example, presents a thin superficial cellular epidermis covering the deep fibrous and vascular derma. The epidermic cells are distinguishable, as in fishes in general, into a deep, a middle, and a superficial layer. In the first, the cells are vertically elongated, in the second more rounded and polygonal, in the third flattened. Many of the cells of the middle layer are of the nature of "mucous cells." They enlarge and become filled with a mucous secretion; and, rising to the surface, burst and discharge their contents, which give rise to the mucous fluid with which the fish's body is covered. The openings of these "mucous cells" remain patent for some time and are to be seen in thin vertical sections. The hyphæ of the spores which attach themselves to the fish may enter by these openings, but even if they do not, the flattened superficial cells certainly offer no greater resistance than does the tough cuticle of a fly. However this may be, sections of young patches of diseased skin show that the hyphæ of the fungus not only traverse the epidermis, but bore through the superficial layer of the derma for a distance, in some cases, of as much as one-tenth of an inch. Each hypha thus comes to have a stem-part, which lies in the epidermis, and a root-part, which lies in the derma. Each of these elongates and branches out. The free ends of the stem-hyphæ rise above the surface of the epidermis and become converted into zoosporangia, more or fewer of the spores of which attach themselves to the surrounding epidermis and repeat the process of penetration. Thus the epidermis and the derma become traversed by numerous hyphæ set close side by side. But, at the same time, these hyphæ send off lateral branches which spread radially, forcing asunder the middle and deeper layers of the epidermic cells, and giving rise to the radiating ridges which are visible to the naked eye in the peripheral part of the patch. The force of the growth of the hyphæ which traverse the epidermis, is made obvious by the curious manner in which, when the central tract of a patch is teased out, the distorted epidermic cells are seen adhering to it, as if they were spitted upon it.

In the derma, the root-hyphæ branch out, pierce the bundles of connective tissue, and usually end in curiously distorted extremities.

The effect of the growth of the stem-hyphæ is to destroy the epidermis altogether. Its place is taken by a thick, felted, mycelium, which entangles the minute particles of sand which are suspended in the water, and thus no doubt constitutes a very irritating application to the sensitive surface of the true skin.

In the true skin, the tracks of the root-hyphæ are not accompanied by any obvious signs of inflammation, but the hyphæ are so close set, that they cannot fail to interfere with the nutrition of the part, and thus bring about necrosis and sloughing. Such sloughing in fact gradually takes place, small vessels give way and bleed, and the burrowing sore, which is characteristic of the advanced stages of the disease, is produced.

The skin of the head may thus be eaten away down to the bone and gristle of the skull, but I have not observed the fungus to enter these. On the scaly part of the skin, the fungus burrows in the superficial and in the deep layer of the pouches of the scales, but I have not observed the scales themselves to be perforated.

When I found that the fungus penetrated the true skin, and thus gained access to the lymphatic spaces and blood-vessels, it became a matter of great interest to ascertain whether the hyphæ might not break up into toruloid segments (as in the case of the *Empusa muscæ*), and thus give rise to general septic poisoning, or fungoid metastasis. However, I have never been able to find any indication of the occurrence of such a process.

But a very important practical question arises out of the discovery that the fungus penetrates into the derma. There is much reason to believe, that if a diseased salmon returns to salt water, all the fungus which is reached by the saline fluid is killed, and the destroyed epidermis is repaired. But the sea water has no access to the hyphæ which have burrowed into the true skin; and hence it must be admitted to be possible, that, in a salmon which has become to all appearance healed in the sea, and which looks perfectly healthy when it ascends a river, the remains of the fungus in the derma may break out from within, and the fish become diseased without any fresh infection. It has not infrequently been observed, that salmon in their upward course became diseased at a surprisingly short distance from the sea, and it is possible that the explanation of the fact is to be sought in the revival of dormant *Saprolegnia*, rather than in new infection. It is to be hoped, that experiments, now being carried on at Berwick, will throw some light on this point, as well as upon the asserted efficacy of sea water in destroying the fungus which it reaches.

These are the chief results of this season's observations on the salmon disease. Incomplete as they are, they appear to me to justify the following conclusions:—

1. That the *Saprolegnia* attacks the healthy living salmon exactly in the same way as it attacks the dead insect, and that it is the sole cause of the disease, whatever circumstances may, in a secondary manner, assist its operations.

2. That death may result without any other organ than the skin being attacked, and that, under these circumstances, it is the consequence partly of the exhaustion of nervous energy by the incessant irritation of the felted mycelium with its charge of fine sand, and partly of the drain of nutriment directly and indirectly caused by the fungus.

3. That the penetration of the hyphæ of the *Saprolegnia* into the derma renders it at least possible that the disease may break out in a fresh-run salmon without re-infection.

4. That the cause of the disease, the *Saprolegnia*, may flourish in any fresh water, in the absence of salmon, as a saprophyte upon dead insects and other animals.

5. That the chances of infection for a healthy fish entering a river, are prodigiously increased by the existence of diseased fish in that river, inasmuch as the bulk of *Saprolegnia* on a few diseased fish vastly exceeds that which would exist without them.

6. That, as in the case of the potato disease, the careful extirpation of every diseased individual is the treatment theoretically indicated; though, in practice, it may not be worth while to adopt that treatment.

II. "On the Conservation of Solar Energy." By C. William Siemens, D.C.L., LL.D., F.R.S., Mem. Inst. C.E. Received February 20, 1881.

The question of the maintenance of Solar Energy is one that has been looked upon with deep interest by astronomers and physicists from the time of La Place downward.

The amount of heat radiated from the sun has been approximately computed, by the aid of the pyrheliometer of Pouillet and by the actinometers of Herschel and others, at 18,000,000 of heat units from every square foot of his surface per hour, or, put popularly, as equal to the heat that would be produced by the perfect combustion every thirty-six hours of a mass of coal of specific gravity=1·5 as great as that of our earth.

If the sun were surrounded by a solid sphere of a radius equal to the mean distance of the sun from the earth (95,000,000 of miles), the whole of this prodigious amount of heat would be intercepted; but considering that the earth's apparent diameter as seen from the sun is only seventeen seconds, the earth can intercept only the 2,250-millionth part. Assuming that the other planetary bodies swell the intercepted heat by ten times this amount, there remains the important fact that $\frac{224999999}{225000000}$ of the solar energy is radiated into space, and apparently lost to the solar system, and only $\frac{1}{225000000}$ utilised.

Notwithstanding this enormous loss of heat, solar temperature has not diminished sensibly for centuries, if we neglect the periodic changes—apparently connected with the appearance of sun-spots—that have been observed by Lockyer and others, and the question forces itself upon us how this great loss can be sustained without producing an observable diminution of solar temperature even within a human lifetime.

Amongst the ingenious hypotheses intended to account for a continuance of solar heat is that of shrinkage, or gradual reduction of the sun's volume suggested by Helmholtz. It may, however, be urged against this theory that the heat so produced would be liberated throughout his mass, and would have to be brought to the surface by conduction, aided perhaps by convection; but we know of no material of sufficient conductivity to transmit anything approaching the amount of heat lost by radiation.

Chemical action between the constituent parts of the sun has also been suggested; but here again we are met by the difficulty that the products of such combination would ere this have accumulated on the surface, and would have formed a barrier against further action.

These difficulties led Sir William Thomson to the suggestion that the cause of maintenance of solar temperature might be found in the circumstance of meteorolites falling upon the sun, not from great distances in space, as had been suggested by Mayer and Waterston, but from narrow orbits which slowly contracted by resistance until at last the meteorolites became entangled in the sun's atmosphere and fell in; and he shows that each pound of matter so imparted would represent a large number of heat units without disturbing the planetary equilibrium. But in considering more fully the enormous amount of planetary matter that would be required for the maintenance of the solar temperature, Sir William Thomson soon abandoned this hypothesis for that of simple transfer of heat from the interior of a fluid sun to the surface by means of convection currents, which latter hypothesis appears at the present time to be also supported by Professor Stokes and other leading physicists.

But if either of these hypotheses could be proved, we should only have the satisfaction of knowing that the solar waste of energy by dissipation into space was not dependent entirely upon loss of his sensible heat, but that his existence as a luminary would be prolonged by calling into requisition a limited, though may be large, store of energy in the form of separated matter. The true solution of the problem will be furnished by a theory, according to which radiant energy which is now supposed to be dissipated into space and irrecoverably lost to our solar system, could be arrested, wholly or partly, and brought back in another form to the sun himself, there to continue the work of solar radiation.

Some years ago it occurred to me that such a solution of the solar problem might not lie beyond the bounds of possibility, and although I cannot claim intimate acquaintance with the intricacies of solar physics, I have watched its progress, and have engaged also in some physical experiments bearing upon the question, all of which have served to strengthen my confidence and ripened in me the determination to submit my views, not without some misgiving, to the touchstone of scientific criticism.

For the purposes of my theory, stellar space is supposed to be filled with highly rarefied gaseous matter, including probably hydrogen, oxygen, nitrogen, carbon, and their compounds, besides solid materials in the form of dust. This being the case, each planetary body would attract to itself an atmosphere depending for its density upon its relative attractive importance, and it would not seem unreasonable to suppose that the heavier and less diffusible gases would form the staple of these atmospheres; that, in fact, they would consist mostly of nitrogen, oxygen, and carbonic anhydride, whilst hydrogen and its compounds would predominate in space.

But the planetary system, as a whole, would exercise an attractive influence upon the gaseous matter diffused through space, and would therefore be enveloped in an atmosphere, holding an intermediate position between the individual planetary atmospheres and the extremely rarefied atmosphere of the stellar space.

In support of this view it may be urged, that in following out the molecular theory of gases as laid down by Clausius, Clerk Maxwell, and Thomson, it would be difficult to assign a limit to a gaseous atmosphere in space and, further, that some writers, among whom I will here mention only Grove, Humboldt, Zoellner, and Mattieu Williams, have boldly asserted the existence of a space filled with matter, and that Newton himself, as Dr. Sterry Hunt tells us in an interesting paper which has only just reached me, has expressed views in favour of such an assumption. Further than this, we have the facts that meteorolites whose flight through stellar, or at all events through interplanetary space, is suddenly arrested by being brought into collision with our earth, are known to contain as much as six times their own volume of gases taken at atmospheric pressure; and Dr. Flight has only very recently communicated to the Royal Society the analysis of the occluded gases of one of these meteorolites taken immediately after the descent to be as follows:—

CO_2	0·12
CO	31·88
H	45·79
CH_4	4·55
N	17·66
	100·00

It appears surprising that there was no aqueous vapour, considering there was much hydrogen and oxygen in combination with carbon, but perhaps the vapour escaped observation, or was expelled to a greater extent than the other gases by external heat when the meteorolite passed through our atmosphere. Opinions concur that the gases found occluded in meteorolites cannot be supposed to have entered into their composition during the very short period of traversing our atmosphere, but if any doubt should exist on this head, it ought to be set at rest by the fact that the gas principally occluded is hydrogen, which is not contained in our atmosphere in any appreciable quantity.

Further proof of the fact that stellar space is filled with gaseous matter is furnished by spectrum analysis, and it appears from recent investigation, by Dr. Huggins and others, that the nucleus of a comet contains very much the same gases found occluded in meteorolites, including "carbon, hydrogen, nitrogen, and probably oxygen," whilst, according to the views set forth by Dewar and Liveing, it also contains nitrogenous compounds such as cyanogen.

Adversely to the assumption that interplanetary space is filled with gases, it is urged that the presence of ordinary matter would cause sensible retardation of planetary motion, such as must have made itself felt before this; but assuming that the matter filling space is an almost perfect fluid not limited by border surfaces, it can be shown on purely mechanical grounds, that the retardation by friction through such an attenuated medium would be very slight indeed, even at planetary velocities.

But it may be contended that, if the views here advocated regarding the distribution of gases were true, the sun should draw to himself the bulk of the least diffusible, and therefore the heaviest gases, such as carbonic anhydride, carbonic oxide, oxygen and nitrogen, whereas spectrum analysis has proved on the contrary a prevalence of hydrogen.

In explanation of this seeming anomaly, it can be shown in the first place, that the temperature of the sun is so high, that such compound gases as carbonic anhydride and carbonic oxide, could not exist within him; it has been contended, indeed, by Mr. Lockyer, that none of the metalloïds have any existence at these temperatures, although as regards oxygen, Dr. Draper asserts its existence in the solar photosphere. There must be regions, however, outside that thermal limit, where their existence would not be jeopardised by heat, and here great accumulation of those comparatively heavy gases that constitute our atmosphere would probably take place, were it not for a certain counterbalancing action.

I here approach a point of principal importance in my argument, upon the proof of which my further conclusions must depend.

The sun completes one revolution on its axis in 25 days, and its diameter being taken at 882,000 miles, it follows that the tangential velocity amounts to 1·25 miles per second, or to 4·41 times the tangential velocity of our earth. This high rotative velocity of the sun must cause an equatorial rise of the solar atmosphere to which Mairan, in 1731, attributed the appearance of the zodiacal light. La Place rejected this explanation on the ground that the zodiacal light extended to a distance from the sun exceeding our own distance, whereas the equatorial rise of the solar atmosphere due to its rotation could not exceed $\frac{9}{20}$ths of the distance of Mercury. But it must be remembered that La Place based his calculation upon the hypothesis of an empty stellar space (filled only with an imaginary ether), and that the result of solar rotation would be widely different, if it was supposed to take place within a medium of unbounded extension. In this case pressures would be balanced all round, and the sun would act mechanically upon the floating matter surrounding it in the manner of a fan, drawing it towards itself upon the polar surfaces, and projecting it outward in a continuous disk-like stream.

By this fan action, hydrogen, hydrocarbons, and oxygen, are supposed to be drawn in enormous quantities toward the polar surfaces of the sun; during their gradual approach, they will pass from their condition of extreme attenuation and extreme cold, to that of compression, accompanied with rise of temperature, until on approaching the photosphere, they burst into flame, giving rise to a great development of heat, and a temperature commensurate with their point of dissociation at the solar density. The result of their combustion will be aqueous vapour and carbonic anhydride or oxide, according to the sufficiency or the insufficiency of oxygen present to complete the combustion, and these products of combustion in yielding to the influence of centrifugal force will flow toward the solar equator, and be thence projected into space.

The next question for consideration is: What would become of these products of combustion when thus rendered back into space? Apparently they would gradually change the condition of stellar material, rendering it more and more neutral, but I venture to suggest the possibility, nay, the probability, that solar radiation would, under these circumstances, step in to bring back the combined materials to a condition of separation by a process of dissociation carried into effect at the expense of that solar energy which is now supposed to be lost to our planetary system.

According to the law of dissociation as developed by Bunsen and Sainte-Claire Deville, the point of dissociation of different compounds depends upon the temperature on the one hand, and upon the pressure on the other. According to Sainte-Claire Deville, the dissociation tension of aqueous vapour of atmospheric pressure and at 2800° C. is 0·5, or only half of the vapour can exist as such, its remaining half being found as a mechanical mixture of hydrogen and oxygen, but that with the pressure, the temperature of dissociation rises and falls, as the temperature of saturated steam rises and falls with its pressure. It is therefore conceivable that the temperature of the solar photosphere may be raised by combustion to a temperature exceeding 2800° C., whereas dissociation may be effected in space at comparatively low temperatures.

These investigations had reference only to heats measured by means of pyrometers, but do not extend to the effects of radiant heat. Dr. Tyndall has shown by his exhaustive researches that vapour of water and other gaseous compounds intercept radiant heat in a most remarkable degree, and there is other evidence to show that radiant energy from a source of high intensity possesses a dissociating power far surpassing the measurable temperature to which the compound substance under its influence is raised. Thus carbonic anhydride and water are dissociated in the leaf cells of plants, under the influence of the direct solar ray at ordinary summer temperature, and experiments in which I have been engaged for nearly three years* go to prove that this dissociating action is obtained also under the radiant influence of the electric arc, although it is scarcely perceptible if the source of radiant energy is such as can be produced by the combustion of oil or gas.

The point of dissociation of aqueous vapour and carbonic anhydride admits, however, of being determined by direct experiment. It engaged my attention some years ago, but I have hesitated to publish the qualitative results I then obtained, in the hope of attaining to quantitative proofs.

These experiments consisted in the employment of glass tubes, furnished with platinum electrodes, and filled with aqueous vapour or with carbonic anhydride in the usual manner, the latter being furnished with caustic soda to regulate the vapour pressure by heating. Upon immersing one end of the tube charged with aqueous vapour in a refrigerating mixture of ice and chloride of calcium, its temperature at that end was reduced to $-32°$ C., corresponding to a vapour pressure, according to Regnault, of $\frac{1}{1800}$ of an atmosphere. When so cooled no slow electric discharge took place on connecting the two electrodes with a small induction coil. I then exposed the end of the tube projecting out of the freezing mixture, backed by white paper, to solar radiation (on a clear summer's day) for several hours, when upon again connecting up to the inductorium, a discharge, apparently that of a hydrogen vacuum, was obtained. This experiment being repeated furnished unmistakable evidence, I thought, that aqueous vapour had been dissociated by exposure to solar radiation. The CO_2 tubes gave, however, less reliable results. Not satisfied with these qualitative results, I made arrangements to collect the permanent

* See "Proc. Roy. Soc.," vol. 30, p. 208, and paper read before Section A, British Association, and printed in full in the Report for 1881, Part I, p. 474.

gases so produced by means of a Sprengel pump, but was prevented by lack of time from pursuing the inquiry, which I purpose, however, to resume shortly, being of opinion that, independently of my present speculation, the experiments may prove useful in extending our knowledge regarding the laws of dissociation.

It should here be observed that, according to Professor Stokes, the ultra-violet rays are in a large measure absorbed in passing through clear glass, and it follows from this discovery that only a small portion of the chemical rays found their way through the tubes to accomplish the work of dissociation. This circumstance, being adverse to the experiment, only serves to increase the value of the result observed.

Assuming, for my present purpose, that dissociation of aqueous vapour was really effected in the experiment just described, and assuming, further, that stellar space is filled with aqueous and other vapour of a density not exceeding the $\frac{1}{2000}$th part of our atmosphere, it seems reasonable to suppose that its dissociation would be effected by solar radiation, and that solar energy would thus be utilised. The presence of carbonic anhydride and carbonic oxide would only serve to facilitate the decomposition of the aqueous vapour by furnishing substances to combine with nascent oxygen and hydrogen. It is not necessary to suppose that all the energy radiated from the sun into space should be intercepted, inasmuch as even a partial return of heat in the manner described would serve to supplement solar radiation, the balance being made up by absolute loss. To this loss of energy must be added that involved in keeping up the circulating movement of the gas, which, however, would probably not be relatively greater than that concerned in the tidal retardation of the earth's rotation. By means of the fan-like action resulting from the rotation of the sun, the vapours dissociated in space would be drawn towards the polar surfaces of the sun, be heated by increase in density, and would burst into flame at a point where both their density and temperature had reached the necessary elevation to induce combustion, each complete cycle taking, however, years to be accomplished. The resulting aqueous vapour, carbonic anhydride and carbonic oxide, would be drawn towards the equatorial regions, and be then again projected into space by centrifugal force.

Space would, according to these views, be filled with gaseous compounds in process of decomposition by solar radiant energy, and the existence of these gases would furnish an explanation of the solar absorption spectrum, in which the lines of some of the substances may be entirely neutralised and lost to observation. As regards the heavy metallic vapours revealed in the sun by the spectroscope, it is assumed that these form a lower and denser solar atmosphere, not participating in the fan-like action which is supposed to affect the light outer atmosphere only, in which hydrogen is the principal factor.

Such a dense metallic atmosphere could not participate in the fan action affecting the lighter photosphere, because this is only feasible on the supposition that the density of the in-flowing current is, at equal distances from the gravitating centre, equal or nearly equal to the outflowing current. It is true that the products of combustion of hydrogen and carbonic oxide are denser than their constituents, but this difference may be balanced by their superior temperature on leaving the sun, whereas the metallic vapours would be unbalanced, and would therefore obey the laws of gravitation, recalling them to the sun. On the surface of contact between the two solar atmospheres intermixture, induced by friction, must take place, however, giving rise perhaps to those vortices and explosive effects which are revealed to us by the telescope in the intermediate or stormy region of the sun, and which have been commented on by Sir John Herschel and other astronomers. Some of the denser vapours would probably get intermixed and carried away mechanically by the lighter gases, and give rise to that cosmic dust which is observed to fall upon our earth in not inappreciable quantities. Excessive intermixture would be prevented by the intermediary neutral atmosphere, the penumbra.

As the whole solar system moves through space at a pace estimated at 150,000,000 of miles annually (being about one-fourth of the velocity of the earth in its orbit), it appears possible that the condition of the gaseous fuel supplying the sun may vary according to its state of previous decomposition, in which other heavenly bodies may have taken part. May it not be owing to such differences in the quality of the fuel supplied that the observed variations of the solar heat may depend? and may it not be in consequence of such changes in the thermal condition of the photosphere that sun-spots are formed?

The views here advocated could not be thought acceptable unless they furnished at any rate a consistent explanation of the still somewhat mysterious phenomena of the zodiacal light and of comets. Regarding the former, we should be able to return to Mairan's views, the objection by La Place being met by a continuous outward flow from the solar equator. Luminosity would be attributable to particles of dust emitting light reflected from the sun, or by phosphorescence. But there is another cause for luminosity of these particles, which may deserve a passing consideration. Each particle would be electrified by gaseous friction in its acceleration, and its electric tension would be vastly increased in its forcible removal, in the same way as the fine dust of the desert has been observed by Werner Siemens to be in a state of high electrification on the apex of the Cheops Pyramid. Would not the zodiacal light also find explanation by slow electric discharge backward from the dust towards the sun? and would the same cause not account for a great difference of potential between the sun and earth, which latter may be supposed to be washed by the solar radial current? May not the presence of the current also furnish us with an explanation of the fact that hydrogen, while abounding apparently in space, is practically absent in our atmosphere, where aqueous vapour, which may be partly derived from the sun, takes its place? An action analogous to this, though on a much smaller scale, may be set up also by terrestrial rotation giving rise to an electrical discharge from the outgoing equatorial stream to the polar regions, where the atmosphere to be pierced by the return flood is of least resistance.

It is also important to show how the phenomena of comets could be harmonised with the views here advocated, and I venture to hope that these occasional visitors will serve to furnish us with positive evidence in my favour. Astronomical physicists tell us that the nucleus of a comet consists of an aggregation of stones similar to meteoric stones. Adopting this view, and assuming that the stones have absorbed in stellar space gases to the amount of six times their volume, taken at atmospheric pressure, what it may be asked, will be the effect of such a mass of stone advancing towards the sun at a velocity reaching in perihelion the prodigious rate of 366 miles per second (as observed in the comet of 1845), being twenty-three times our orbital rate of motion. It appears evident that the entry of such a divided mass into a comparatively dense atmosphere must be accompanied by a rise of temperature by frictional resistance, aided by attractive condensation. At a certain point the increase of temperature must cause ignition, and the heat thus produced must drive out the occluded gases, which in an atmosphere 3000 times less dense than that of our earth would produce $6 \times 3000 = 18{,}000$ times the volume of the stones themselves. These gases would issue forth in all directions, but would remain unobserved except in that of motion, in which they would meet the interplanetary atmosphere with the compound velocity, and form a zone of intense combustion, such as Dr. Huggins has lately observed to surround the one side of the nucleus, evidently the side of forward motion. The nucleus would thus emit original light, whereas the tail may be supposed to consist of stellar dust rendered luminous by reflex action produced by the light of the sun and comet combined, as foreshadowed already by Tyndall, Tate, and others, starting each from different assumptions.

These are in brief the outlines of my reflections regarding this most fascinating question, which I venture to put before the Royal Society. Although I cannot pretend to an intimate acquaintance with the more intricate phenomena of solar physics, I have long had a conviction, derived principally from familiarity with some of the terrestrial effects of heat, that the prodigious and seemingly wanton dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that it may be arrested and returned over and over again to the sun, in a manner somewhat analogous to the action of the heat recuperator in the regenerative gas furnace. The fundamental conditions are :—

1. That aqueous vapour and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That these dissociated vapours are capable of being compressed into the solar photosphere by a process of interchange with an equal amount of reassociated vapours, this interchange being effected by the centrifugal action of the sun itself.

If these conditions could be substantiated, we should gain the satisfaction that our solar system would no longer impress us with the idea of prodigious waste through dissipation of energy into space, but rather with that of well-ordered self-sustaining action, capable of perpetuating solar radiation to the remotest future.

March 9, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The Right Hon. Anthony John Mundella, whose certificate had been suspended as required by the Statutes, was balloted for and elected a Fellow of the Society.

The following Papers were read :—

I. Experiments to Determine the Value of the British Association Unit of Resistance in Absolute Measure." By LORD RAYLEIGH, F.R.S., Professor of Experimental Physics in the University of Cambridge. Received February 15, 1882.

(Abstract.)

This paper contains an account of a repetition by Dr. Schuster, Mrs. Sidgwick, and myself, of the British Association experiment on the unit of resistance with an improved apparatus. Three distinct series of observations were taken, of which the two first were more or less imperfect. In the third series an extraordinary concordance in the results obtained on different occasions at the same speed of rotation was arrived at, but the numbers corresponding to the four speeds

could not be perfectly harmonized on the basis of an *à priori* calculation of the self-induction.

Table VII.—Third Series.

Number of teeth	60.	45.	35.	30.	Mean.
Resistance of standard at 13°, uncorrected	23·619	23·621	23·630	23·638	23·627
Correction proportional to square of speed	0·006	0·011	0·018	0·025	
Resistance of standard at 13°, corrected	23·613	23·610	23·612	23·613	23·612

Table VII gives the results of this series. The "number of teeth" in the first row is inversely as the speed of rotation. The second row gives the resistance of a certain platinum-silver standard at 13° in absolute measure, as calculated with a value of the self-induction derived from evidence independent of the spinnings. The simple mean of these numbers is 23·627 ($\times 10^9$ C.G.S.), but they exhibit a well-marked tendency to rise with the speed. In the third row are numbers proportional to the squares of the speeds, by subtraction of which a practically perfect agreement is arrived at. The mean 23·612 thus represents the result of the investigation, if the effect of self-induction be determined from the spinnings themselves, and is to be preferred for reasons explained in the paper to the simple mean 23·627. The difference is, however, less than one part in a thousand.

The resistance at 13° of the same coil in terms of B.A. units is 23·935, from which we find

$$1 \text{ B.A. unit} = \cdot 98651 \, \frac{\text{earth quadrant}}{\text{second}}.$$

This number is somewhat lower than that which we obtained (·9893) with the original apparatus,* but it agrees with that required to reconcile Dr. Joule's thermal determinations. Rowland's value is distinctly higher (·9911), while Kohlrausch obtained 1·02. No satisfactory reconciliation of these results is arrived at, but some remarks are made upon the relative merits of the various methods.

* "Proc. Roy. Soc.," vol. 32, p. 141.

II. "Contributions to the Anatomy of the Central Nervous System in Vertebrate Animals. Sub-section I. Teleostei. Appendix. On the Brain of the Mormyridæ." By ALFRED SANDERS, M.R.C.S. Communicated by Professor HUXLEY, LL.D., F.R.S. Received February 16, 1882.

(Abstract.)

The author, after a preliminary sketch of the literature of the subject, and a description of his method of hardening and staining, proceeds to give an idea of the external aspect of the central nervous system in the Mormyridæ.

Taking as an example the brain of the *Hyperopisus dorsalis*, he describes it as comparable to that of an ordinary teleostean fish to which two additions have been made, namely, an organ situated in the region in front of the cerebellum, which grows out in the form of plates, from a pair of stalks. These plates, or wings as they may be termed, become folded in every direction, and breaking through the tecta lobi optici, and repressing them to the base of the brain, they cover over all the remaining lobes of that organ.

It is only the tecta lobi optici which undergo displacement, the tori semicirculares retain nearly their usual position, so as to become related to the former as an egg to the egg-cup, or an oyster to its shell.

On the outer side of the plates are minute ridges running mostly longitudinally, in close proximity to each other; the parts where these ridges become external are of a pinkish colour when fresh, but where the plates are folded on themselves, the inner side of the wings becomes external, and shows a white colour under the same circumstances.

These folds take place when the plates have grown sufficiently to reach the walls of the skulls, and are arranged as follows:—the plate which grows towards the anterior end of the skull turns backwards; that which grows towards the summit of the skull turns inwards; that which grows outwards turns upwards, while that which grows backwards ends in a free edge, and conceals the second of the additional parts alluded to above.

This exists in the form of a large nearly spherical tuberosity placed behind the cerebellum, in or over the region of the fourth ventricle.

The author then gives an account of the microscopic anatomy of this brain. Passing lightly over the remainder of the lobes, which resemble in structure those of the ordinary teleostei, and noticing in passing that the composition of the tecta lobi optici is much simplified, he proceeds to describe the structure of the cerebellum. He finds that

this presents the four layers usually found in the corresponding lobe in the teleostei, namely, counting from the outside, the molecular, the intermediate—which includes the Purkinjé cells—the granular, and the fibrous; the latter consisting of nerve-fibres on their way to the crura cerebelli.

Noticing Denissenko's* paper, and his discovery of two species of cells in the granular layer of the cerebellum, the author remarks that he was unable to find them, even by using Denissenko's own method. He then discusses the cause of the striation in the molecular layer, which he attributes in a great measure, but not entirely, to prolongations from the epithelial layer of cells which cover the surface of the cerebellum. Incidentally he mentions that he has traced an axis cylinder process of a Purkinjé cell into a medullated nerve-fibre.

He then goes on to describe the structure of the organ in front of the cerebellum. This he finds consists of two parts, a central continuation of the cerebellum, having precisely the same structure and arrangement, and two lateral parts spreading out one on each side, like wings.

The plates which form these lateral wings consist of minute cells, resembling those found in the granular layer of the cerebellum. Each ridge has four layers corresponding to those found in the cerebellum, arranged in a slightly different manner. The molecular layer comes first, then the granular and intermediate layers mingled together, and last of all, the fibrillæ from the fibrous layer. The molecular layers of contiguous ridges are placed in close contiguity with a process from the pia mater interposed between them; the granular and intermediate layers come next, consisting of cells of different sizes, connected together by a network of fibrillæ. The smaller cells resemble those of the granular layer of the cerebellum; the larger ones are intermediate between the last, and the Purkinjé cells to which they lead up. These latter are arranged in a single layer; they are smaller in size than the corresponding cells in the cerebellum, and usually oval or fusiform in shape; they generally have two processes, one, the protoplasmic process, directed towards the molecular layer, and the other the axis-cylinder process, turned towards the bundle of fibrillæ which is derived from the fibrous layer, and which, passing between two contiguous ridges on the side opposite the molecular layer, forms the boundary between them.

In some parts, however, these cells are arranged in groups, viz., where the bending of the wings causes bays and recesses in the ridges; here they are polygonal in shape and present several processes. The sides of the ridges are inserted into the plates or wings of granular layer cells, by conical processes.

* "Zur Frage ü. d. Bau d. Kleinhirnrinde," "Arch. f. Mik. Anat.," Bd. xiv, 1877.

The large tuberosity situated behind the cerebellum is termed by the author the tuberculum impar, and consists of six layers, counting from the outside.

1. The first layer has small cells which become deeply coloured by the staining fluid.

2. The second contains sections of obliquely directed nerve-fibres.

3. The third is smoothly granular and does not become so highly coloured as the outside layer, but shows faint indications of radial striations.

4. The fourth is a narrow stratum of moderately sized cells of varying dimensions, which become intensely coloured by the staining fluid.

5. The fifth consists of a complex of nerve-fibres.

6. The sixth layer only found at the anterior end of the tubercle is composed of finely granular material; the corresponding portion of the posterior end is occupied by a circular space.

In addition to these six layers there is intercalated between the first and second layers a body of granular neuroglia, in which extremely large cells are collected; at the anterior end of the tuberculum impar, this structure takes the place of the first layer and becomes interposed between the tubercle in question and the cerebellum.

The author then discusses the modes of origin of the nerves which are present in these fishes. The trochleares and the abducentes appear to be absent. The trifacial and the vagus, in addition to their ordinary origins, derive the greater number of their fibres from the tuberculum impar, the former from the anterior end, the latter from quite the posterior edge. The facial and the glossopharyngeal are parts of these two nerves respectively.

The author finds, contrary to the opinion of Bellonci,* that the optic nerve has an origin from the hypoarium as well as from the tecta lobi optici. The other nerves arise as in Teleostei.

The author then proceeds to indicate the probable homologies of these two extraordinarily developed organs. Taking the brain of a Ballan wrasse (*Labrus maculatus*) and examining the part which is generally termed the valvula cerebelli, he finds that it has a central part resembling the cerebellum in structure, together with a wing on each side, occupying much more of the ventricle of the optic lobe than in many other Teleostei.

These wings are formed by an extension of the molecular layer of the central part, which even here shows two or three folds based on an extension of the granular layer. He therefore puts forward the idea that if these wings of the valvula cerebelli of the *L. maculatus*

* "Ueber d. Ursprung des Nervus Opticus und den feineren Bau des Tectum Opticum." "Zeitsch. f. Wiss. Zool.," Bd. xxxv, 1880.

were to continue to increase indefinitely, an organ resembling the highly developed structure in the Mormyridæ would result. This latter then may be looked upon as homologising with the valvula cerebelli and its wings in the ordinary teleostean.

With regard to the body which is placed behind the cerebellum, the author points out that the Cyprinidæ possess a well-known tuberosity occupying a corresponding position, which is termed by writers the tuberculum impar; this, in conjunction with the vagal tuberosities of the medulla oblongata, presents layers comparable to those existing in the structure in question belonging to the Mormyridæ; he therefore suggests that the homology of this exaggerated tuberosity in these fishes is to be looked for in the tuberculum impar together with the vagal tuberosities of the Cyprinidæ, the increased size in the former species having caused it to include the origin of the trifacial in addition to that of the vagus.

In conclusion, the author offers some criticism of the ideas lately put forward by Fritsch* as to the homologies of the various parts of the brain in fishes, the key to the whole of which lies in his interpretation of the tecta lobi optici, which he takes to be the persistent cortex of the primary anterior vesicle† of the brain of the embryo, and consequently to belong to the thalamencephalon, and not to the mesencephalon.

In reply to this the present writer points out that the homologies of all the other parts of the brain in Teleostei may be deduced from the position of the pineal gland, the infundibulum, and the ganglion of origin of the oculomotorius.

From this line of argument he maintains that the tecta lobi optici correspond to the anterior pair of the corpora quadrigemina, and consequently belong to the mesencephalon, and not to the thalamencephalon. Finally he remarks that the brain in Teleostei would not be in accordance with the remainder of their organisation, if all the parts of a mammalian cerebrum could be distinguished in it, even in a comparatively rudimentary state as is maintained by Fritsch.

III. "On the Spectrum of Carbon." By G. D. LIVEING, M.A., F.R.S., Professor of Chemistry, and J. DEWAR, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received February 23, 1882.

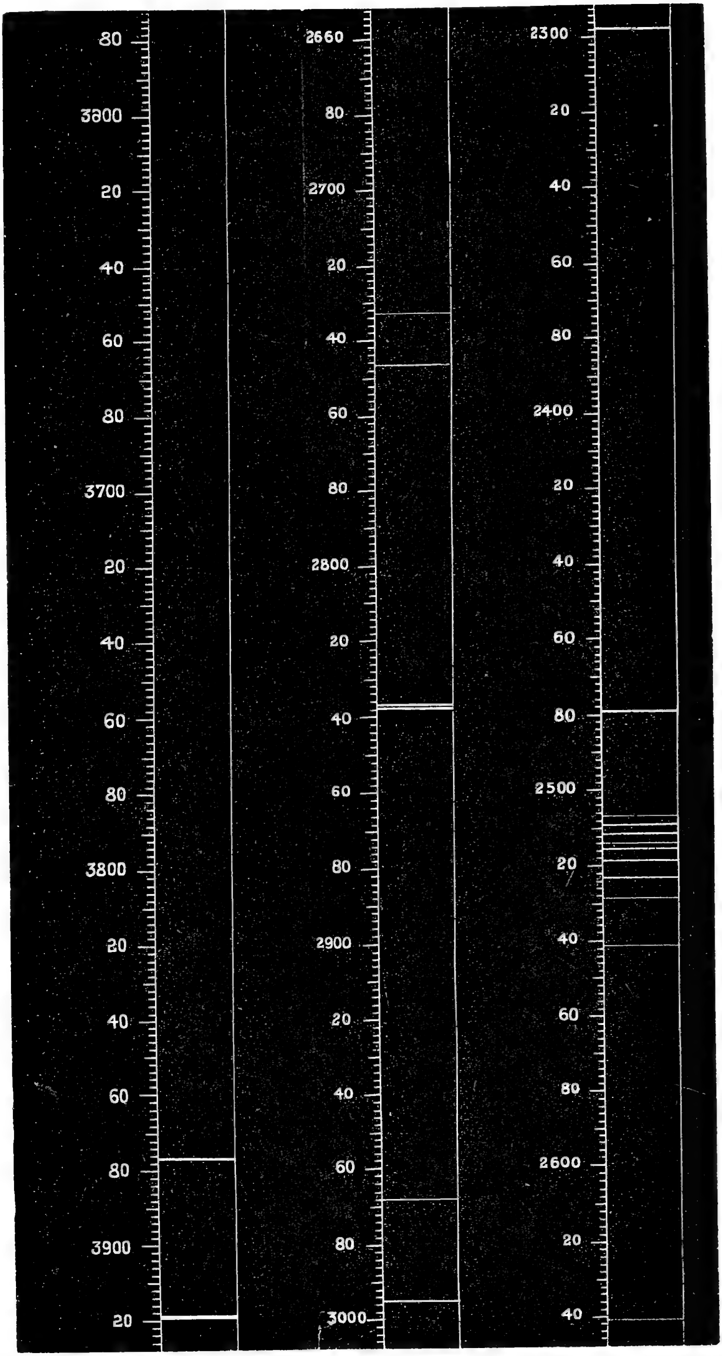
The spectroscopic investigations we have communicated to the Society "On the Reversals of the Lines of Metallic Vapours," have

* "Unters. ü. d. feineren Bau des Fischgehirn." Berlin, 1878.

† "Primäres Vorderhirn," *loc. cit.*

shown the importance of a thorough and accurate knowledge of the ultra-violet spectra of the elements, for it is in the lines of short wave-length as a rule that the greatest emissive power is manifested, and they are therefore most readily reversed. Thus we have succeeded in reversing upwards of 100 lines in the ultra-violet spectrum of iron ("Proc. Roy. Soc.," vol. 32, p. 404). The necessity for accurate data in regard to this region of the spectrum led us to make a long study of the spectrum of magnesium, and the results of this investigation appeared in the volume of the "Proc. Roy. Soc." just cited. Having had occasion to examine the origin of the different fluted spectra of carbon, it became apparent that a complete knowledge of the relations of these spectra to the simple spectrum of the element could only be reached by the help of a complete record of the line spectrum. Ångström and Thalén, in their memoir "On the Spectra of the Metalloids" (Nova Acta Reg. Soc. Upsal., Ser. iii, vol. ix), give a map and table of wave-lengths of the lines due to carbon in the visible part of the spectrum, as distinguished from the fluted spectra given by compounds of carbon, namely, carbonic oxide, cyanogen, and acetylene. These lines, they state, always appeared when very powerful induction sparks were passed through the vapour of any compound of carbon, or between carbon electrodes. This line spectrum is remarkable for simplicity, consisting of eleven lines, of which the single line in the yellow, followed by a triple group in the green, and a very strong line in the blue, recall vividly the spectrum of magnesium; and as we know two modifications of the spectrum of magnesium which seem to be due respectively to the oxide and a hydride, the parallel between the behaviour of the two elements is the more striking. The plates of the ultra-violet spectra of the metals by the late Professor W. A. Miller ("Phil. Trans.," 1864) include plates of the spark taken between metallic electrodes in different compounds of carbon, which show with sufficient clearness that there are some five groups of lines in the ultra-violet spectrum of this element. In the observations here described we have preferred taking intense induction sparks between pure graphite poles in different gases.

The accompanying figure represents the ultra-violet spectrum of carbon to a scale of wave-lengths within the range of the rays transmitted through calcite. The lines figured have been observed in photographs of the spark of a large induction coil, having a large Leyden jar in connexion with the secondary coil, between poles of purified graphite in air, carbonic acid gas, hydrogen, and coal-gas. The same lines have been observed in photographs of the spark between iron, and between aluminium poles in carbonic acid gas. By comparing the photographs taken under these different circumstances, we have, we believe, eliminated the air lines, which are numerous and strong in the region between H and T, and will form the subject of a



Ultra-violet Spectrum of Carbon.

future communication, and also the metallic lines which graphite, purified with the utmost care, still exhibited.

The graphite was purified by being stirred in fine powder into fused potash, and subsequent treatment with aqua regia, by prolonged ignition in a current of chlorine, and by treatment with hydrofluoric acid. The well washed powder was afterwards compressed into blocks by hydraulic pressure between platinum plates, and from these blocks the electrodes employed were cut. Notwithstanding the purification the photographs of the spark between these electrodes still showed very distinctly lines of magnesium and iron. This fact shows the extreme difficulty of getting rid of all impurity, and the caution which is requisite in any reasoning depending on the assumption of chemical purity in the materials employed. It is very possible that the magnesium and even the iron in this case may have been due to oxides of those metals in the floating dust of the laboratory, which we know always contains sodium compounds, and which at Cambridge, where the water, soil, and bricks contain sensible quantities of lithium, almost always shows traces of that element.

The wave-lengths of the strongest carbon lines were determined by means of a Rutherford diffraction grating having 17,296 lines to the inch. The measures were made in the following way: The collimator and telescope of the goniometer were first centred by the instrument maker's marks. The telescope was then more carefully adjusted for centre by directing it on to a distant mark, taking the reading of the circle, turning the arm carrying the telescope through 180° and reversing the telescope, whereby the mark was again brought into the field of view, and adjustments were then made until the mark had the same position on the cross-wires in both positions of the telescope. The grating was next placed in position, and, after adjustment to the vertical plane was brought very nearly at right angles to the axis of the collimator by turning it until the sodium D lines in the spectra of the second order were observed to fall at equal distances on either side of the collimator. The small photographic slide, containing the sensitive plate, fitted the telescope in place of the eye-piece, and so could easily be turned about an axis coincident, or nearly so, with the optic axis of the telescope. In taking a measurement of the position of a line the approximate wave-length was first found by interpolating between the nearest cadmium or other lines of known wave-length in photographs taken with calcite prisms. The telescope was then set to the angle corresponding to this approximate wave-length for the spectrum of the fourth order. The lower half of the slit was closed by a shutter, and the photographic slide having been adjusted for level, the plate was exposed to the light which came through the upper half of the slit, and gave an image of the lines in the lower half of the field. When this exposure was completed, the photographic slide was turned round through 180° about the axis of the telescope, so as to bring to the top that part of the sensitive plate which had been before lowest. It was then exposed a second time, and thus two images of the same line were impressed on the plate, which were necessarily at equal distances on either side of the point where the axis of the telescope met the plate. By a subsequent measurement with a micrometer under a microscope of the distance between the two images, and the conversion of this distance into angular measure, a correction was found, which was added to, or subtracted from, the reading of the circle to get the exact deviation of the ray producing the line under observation. Another photograph of the same line was next taken in the same way as before, except that the telescope was placed at the corresponding angle on the other side of the collimator. From the two angles thus found, the wave-length of the line was calculated. The process was repeated three or four times for each line, and the mean wave-length thus found for carbon lines were 2296·5, 2478·3, 2509·0, 2511·9, 2836·3, and 2837·2. The numbers deduced from the different photographs of the same line differed from one another in the last figure only, so that we are justified in assuming the first four figures to be accurate in each case. The wave-lengths of the remaining lines were obtained by interpolation from measures of photographs taken with a train of two calcite prisms of 30° each, and one of 60°, on which the iron as well as the carbon lines were shown. The wave-lengths of the iron lines used in the interpolations were deduced from photographs taken with the grating in the same way as that above described for the carbon lines. The wave-lengths thus found for the remaining carbon lines are given in the table below.

In taking the photographs of the spark, the induction coil was sometimes worked by a De Meritens magneto-electric machine, and in that case the stream of sparks was not only extremely brilliant, but produced a deafening roar. Notwithstanding this character of the spark, the photographs, when the spark was taken in air, between poles of purified graphite, showed, besides the carbon lines above described, the set of six cyanogen flutings in the blue very distinctly, and those between K and L, and those near N, strongly developed. On the other hand, when the spark was taken in carbonic acid gas, these flutings almost entirely disappeared, and would no doubt have disappeared entirely, if the last traces of air had been removed from the apparatus.

Table of Carbon Lines.

Authors.	Colour.	Wave-length.	Intensity.
Ångström and Thalén...	Red....	6583·0	2
		6577·5	1
	Orange .	5694·1	4
		5660·9	4
		5646·5	3
		5638·6	5
	Yellow....	5379·0	6
	Green ..	5150·5	4
		5144·2	3
		5133·0	5
	Indigo....	4266·0	1, diffuse
Liveing and Dewar.....	Ultra-violet...	3919·3	2, diffuse
		3876·5	4, ,,
		2995·0	4, very diffuse
		2968·0	5, ,, ,,
		2837·2	2
		2836·3	2
		2746·5	3, very diffuse
		2733·2	6, ,, ,,
		2640·7	4, ,, ,,
		2541·5	6
		2528·2	5
		2523·6	5
		2518·7	5
		2515·8	4
		2514·0	5
		2511·9	2
		2509·0	3
		2506·6	5
		2478·3	1
		2296·5	3

Spectrum of Incandescent Carbon Filaments.

We have also examined the spectrum of Swan's incandescent lamps. So long as the carbon thread is unbroken, it emits a continuous spectrum, on which neither bright nor dark lines are visible. By gradually increasing the number of cells in the battery, until the thread gave way, we found at the instant of fracture, for a small fraction of a second only, that a set of flutings in the green appeared. In some of those lamps we observed, when the current was nearly as much as the carbon thread would bear without rupture, that a sort of flame appeared in the lamp. On examining the spectrum of this flame, it gave the flutings of carbonic oxide very distinctly, and we made sure that they were those of carbonic oxide, and not those of hydrocarbons, by comparison with the bands of a Bunsen burner. Closer examination showed that this flame was strongest about the junction of the carbon thread with one of the conducting wires, and that on reversing the current, it shifted from one wire to the other, and the wire about which it appeared was always the positive electrode. In fact, the flame was the glow of the positive pole attending a discharge in rarefied gas; when the resistance of the carbon thread became too great in proportion to the intensity of the current, the discharge began to occur through the rarefied atmosphere within the envelope of the lamp. The spectrum showed that this atmosphere contained carbonic oxide.

By interposing different flames between the incandescent lamp and the slit of the spectroscope, we have been able to make some comparisons of the probable temperatures of the flames and filament. For this purpose a lens of 3 inches focal length was placed 6 inches in front of the slit, and an image of a horizontal part of the incandescent carbon thread formed by it across the (vertical) slit. The appearance in the field of view of the spectroscope was a narrow continuous spectrum extending all across the field. When a flame was interposed between the lens and the slit, the bright lines of the flame were seen above and below the narrow continuous spectrum, and in some cases were continued across it, or were seen reversed upon it. When the flame was that of a Bunsen burner in which was a platinum wire with sodium carbonate, the yellow sodium lines were seen bright above and below the continuous spectrum of the carbon thread, but reversed where they crossed it. When lithium was substituted for sodium in the flame, the red lithium line was also seen bright above and below the continuous spectrum, but reversed where it crossed it. When an oxyhydrogen jet was substituted for the Bunsen burner, and sodium carbonate held in it, the yellow sodium lines were not only bright above and below the continuous spectrum of the carbon, but showed as bright lines where they crossed it, in fact they were conspicuously brighter than the carbon. When coal-gas was substituted for hydrogen in the jet, the same appearance presented itself, only the sodium lines were not so much brighter than the carbon as they were before. Fifty Grove's cells were used with the incandescent lamp, which were as many as could be used without danger of rupturing the threads. When barium chloride was held in the hydrogen flame fed with only a little oxygen, the bright green line of barium (wave-length 5534) was well seen above and below the continuous spectrum, but could not be traced either bright or dark across it. When a flame of cyanogen burning in air was interposed, the bright bands of that flame could be seen above and below the continuous spectrum, but could not be traced either bright or dark across it. When sodium carbonate was held in this flame the yellow sodium lines were seen feebly reversed where they crossed the spectrum of the incandescent lamp. We infer from these experiments that the emissive power of the carbon thread for light of the refrangibility of the D lines is nearly balanced by that of sodium at the temperature of the flame of cyanogen burning in air, but is sensibly less than that of sodium, at the temperature of a jet of coal-gas and oxygen, much less than that of sodium in the oxyhydrogen jet. This seems to render it probable that the temperature of the incandescent thread is not far different from that of a cyanogen flame burning in air (or rather the temperature it conveys to the sodium in it), but is less than that of an oxyhydrogen flame, though this does not necessarily follow from the experiments, inasmuch as the radiation of the sodium is so much more limited as to range than that of the carbon. When a Bunsen burner or a gas blowpipe flame was interposed between the lens and slit, no reversal of the hydrocarbon bands could be seen. When magnesium was burnt between the lens and slit, the magnesium lines (*b*) were seen bright, eclipsing the carbon. Possibly the smoke of magnesia may have considerably helped to eclipse the light of the carbon.

IV. "Preliminary Report to the Solar Physics Committee on a Comparison for Two Years between the Diurnal Ranges of Magnetic Declination as recorded at the Kew Observatory, and the Diurnal Ranges of Atmospheric Temperature as recorded at the Observatories of Stonyhurst, Kew, and Falmouth." By BALFOUR STEWART, LL.D., F.R.S., Professor of Physics at Owens College, Manchester. Communicated to the Royal Society by permission of the Solar Physics Committee. Received January 25, 1882.

1. In a paper communicated to this Society, and published in its "Proceedings" (vol. 32, p. 406), evidence was brought forward tending to show that what may be termed declination-range weather takes 1·6 days to pass from Toronto to Kew; that is, the same phase occurs 1·6 days later at Kew than at Toronto. And in a previous paper (*op. cit.*, vol. 29, p. 308) evidence was brought forward tending to show that temperature-range weather takes about 8 days to pass between these two places.

In this last-mentioned paper an attempt was likewise made to show that there is a similarity between magnetical and meteorological changes, and that both are due to the sun. This result has been confirmed by subsequent discussion, and there seems reason to suppose that in America both magnetical and meteorological changes follow very quickly after the solar changes which produce them.

If this be true, if the two kinds of allied weather start together at America, or nearly together, and if the magnetical moves in the same direction as the meteorological weather, but only quicker than it, then it is not unreasonable to suppose that the Kew magnetical weather of to-day may be found to resemble the Kew meteorological weather six or seven days later on.

It is this point which I have endeavoured to test in the present communication by comparing together the variations of declination-range and those of temperature-range at Kew during the years 1871 and 1872.

2. Bearing in mind, however, the local nature of meteorological phenomena, instead of confining myself to Kew alone, I have taken the means of the daily temperature-ranges at Stonyhurst, Kew, and Falmouth, these three forming the chief stations in England of the Meteorological Council, to whose kindness I am indebted for a list of the daily temperature-ranges at these three places for the years 1871 and 1872.

These mean ranges have been compared with the corresponding Kew declination-ranges, excluding disturbances, for which I am indebted to the kindness of the Kew Committee. This comparison has been made after the following method:—

3. The meteorological material, as already mentioned, consists of a series of the daily temperature-ranges at Stonyhurst, Kew, and Falmouth, recorded in degrees Fahrenheit and tenths of a degree. As the results are merely comparative, decimal points have been omitted; also, instead of taking means of the daily temperature-ranges at these three places, it has only been deemed necessary to record the sums of these ranges, thereby saving the division by *three* for each day. A specimen of these sums is exhibited in Table I, column 2. Furthermore, in order somewhat to equalise or tone down individual fluctuations, daily sums of four of the numbers of column 2 are recorded in column 3.

Again, as it is fluctuations of small period, say twenty-four or twenty-five days, which we wish to investigate, column 4 is made to contain means of twenty-five of the numbers of column 3, this mean being placed opposite to that number of column 3 which has the middle or thirteenth place in the series of twenty-five. Finally, the differences between corresponding numbers of columns 3 and 4 are exhibited in column 5, these being taken to represent the fluctuations we are in search of, the sign *minus* denoting defect, and the sign *plus* excess, in the observed values of column 3 with reference to the mean or normal values of column 4.

4. These various peculiarities of the method will be perceived from the following table:—

Table I.—Exhibiting the method of forming a series of Fluctuations of Temperature-Range.

Col. 1. Date. 1872.	Col. 2. Sums of ranges F + K + S.	Col. 3. Sums of 4 values of Col. 2.	Col. 4. Means of 25 values of Col. 3.	Col. 5. Differences, Col. 3, Col. 4.
January 1.....	244			
„ 2.....	185	963		
„ 3.....	263	1028		
„ 4.....	271	1082		
„ 5.....	309	1040		
„ 6.....	239	984		
„ 7.....	221	908		
„ 8.....	215	958		
„ 9.....	233	1089		
„ 10	289	1154		
„ 11.....	352	1200		
„ 12.....	280	1158		
„ 13.....	279	1110		
„ 14.....	247	1091	993	+ 98
„ 15.....	304	1131	986	+145
„ 16.....	261	1132	975	+157
„ 17.....	319	1110	963	+147
„ 18.....	248	1038		
„ 19.....	282	981		
„ 20.....	189	944		
„ 21.....	262	857		
„ 22.....	211	905		
„ 23.....	195	813		
„ 24.....	237	744		
„ 25.....	170	728		
„ 26.....	142	686		
„ 27.....	179	768		
„ 28.....	195	757		
„ 29.....	252	787		
„ 30.....	131			
„ 31.....	209			

5. The numbers representing the diurnal ranges of declination at Kew are derived by means of a measuring instrument applied to the magnetograph curves, and are recorded in decimals of an inch. As the results are merely comparative, decimal points have been omitted. These numbers have been treated in the same way in which the numbers in column 2 of the above table are treated; in fine, the temperature and declination-ranges have had applied to them precisely the same method of treatment.

Ultimately we obtain, as in the case of the temperature-ranges, a column representing declination fluctuations, and comparable with column 5.

6. In Table II the temperature-range and declination-range fluctuations are exhibited side by side for the various months of the years 1871 and 1872.

Table II.—Comparison of Declination-range and Temperature-range Fluctuations for the Year 1871.

Day.	January.		February.		March.		April.		May.		June.	
	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.
1	+ 43	− 31	+ 80	−242	+ 69	+367	−290	−420	−264	+ 70	+ 82	−138
2	− 49	−155	+267	−118	−102	+663	−224	−312	−330	+ 41	+ 41	− 85
3	− 78	− 53	+281	− 68	−157	+644	+114	−128	−221	+184	+174	− 83
4	−195	+ 54	+193	− 77	−161	+284	+ 82	− 50	−208	+206	+329	+ 27
5	− 66	+141	+284	− 27	−227	−148	+331	+153	−291	+252	+465	+ 19
6	− 23	+136	+ 43	− 12	− 33	−380	+373	+301	−471	+619	+499	− 8
7	+ 42	+ 34	+ 13	− 17	+ 11	−230	+271	+334	−545	+279	+477	− 81
8	− 3	+ 44	+ 35	+ 61	− 6	−112	− 13	+399	−640	+112	+335	+ 14
9	−151	− 22	− 87	+ 18	+ 14	− 7	+ 69	+437	−484	− 35	+269	+ 74
10	−233	− 26	−405	+139	− 50	− 75	+153	+307	−334	−222	+127	+217
11	−148	+164	−380	+223	+ 38	−278	+161	+188	−282	−206	− 42	+271
12	+ 95	+124	−260	+141	+222	−325	+295	+152	− 43	−209	− 60	+109
13	+113	+ 74	−282	+200	+397	−339	− 10	−124	+215	−167	− 83	− 2
14	+170	+150	+ 89	− 25	+502	−325	−422	−243	+467	−161	+ 61	−131
15	+117	− 96	+ 96	−103	+163	−125	−340	−234	+727	− 50	+106	−273
16	−131	− 64	− 33	− 59	+155	− 37	−306	−381	+678	+ 7	+ 79	−281
17	−102	− 2	− 65	−176	− 74	− 29	−279	−298	+616	− 30	− 99	−265
18	+ 15	+ 43	−132	−155	−151	+112	− 38	−246	+441	−163	−385	−218
19	− 32	+ 82	−146	−179	+ 35	+ 78	− 40	−244	+247	− 39	−386	−234
20	+ 88	+ 53	− 42	− 83	+ 16	+101	+163	−100	− 13	+ 78	−392	−251
21	+ 96	+ 30	+ 13	+ 40	− 33	+343	+346	−111	− 32	+117	−243	−297
22	− 19	− 90	+118	+ 48	−160	+512	+437	− 98	−298	+412	−229	−330
23	−115	−122	+186	+ 29	− 99	+650	+353	− 61	−809	+343	− 40	−179
24	−218	− 83	+141	− 31	− 82	+643	+ 84	− 31	−568	+129	+ 6	+ 53
25	−229	+ 20	+115	− 96	− 61	+409	+ 98	− 31	−793	+ 92	+ 18	+440
26	−260	+ 98	+133	−158	− 63	+ 91	+228	− 91	−701	− 81	+144	+475
27	−109	+ 92	+ 33	−173	− 30	− 92	+569	−114	−270	− 42	− 24	+378
28	− 15	− 29	− 33	+ 26	− 80	−227	+761	−211	−289	+239	+ 39	+283
29	+ 14	−223			− 77	−303	+481	−158	− 50	+150	+209	+142
30	+ 72	−295			−260	−325	+202	− 15	+ 45	+193	+426	+149
31	+ 49	−265			−251	−421			+148	+ 53		

Day.	July.		August.		September.		October.		November.		December.	
	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.
1	+422	+112	+203	+291	−266	−132	+101	−135	+ 43	−520	−470	− 52
2	+317	+ 0	+343	− 16	−259	−148	− 34	− 18	+ 4	−514	−393	+ 10
3	+ 75	−103	+218	− 79	−131	− 7	+ 77	+120	− 96	−377	−309	+170
4	−210	−101	+302	−182	+ 93	+111	+243	+ 57	− 39	−293	−306	+151
5	−266	− 79	+188	−100	− 33	+202	+129	+ 15	− 29	−274	−185	+129
6	−354	−102	−124	+121	+ 8	+388	+170	+ 18	−121	−148	− 97	+252
7	−236	−129	−114	+234	+124	+232	+107	+ 41	− 69	− 80	+209	+172
8	−112	− 71	−181	+397	− 1	+ 18	+ 6	+225	−198	+ 16	+228	+114
9	− 88	− 82	−185	+344	+282	− 25	− 78	+251	−245	+225	+261	+153
10	−109	− 29	−206	+513	+188	−134	− 57	+283	−132	+400	+166	+136
11	− 48	− 12	−208	+574	+ 33	−174	+ 84	+278	− 67	+522	+111	+ 79
12	− 22	−110	−155	+413	+122	−209	+152	+219	+107	+610	+223	+ 26
13	+148	− 65	− 97	+289	+121	−165	+213	+251	+329	+ 97	+160	−107
14	+375	+ 57	− 52	+149	+ 80	−157	+288	+ 84	+334	+234	+167	−106
15	+434	+ 96	+ 26	− 28	+353	− 94	+121	−116	+227	+ 78	+148	+ 12
16	+437	+214	+194	−197	+419	− 72	+187	−203	+141	+ 75	+106	+ 55
17	+405	+264	+378	−317	+318	−101	+300	−325	− 40	+142	+170	+ 81
18	+106	+ 96	+316	−419	+335	−100	+118	−211	−119	+211	+209	+ 35
19	+ 38	− 67	+269	−488	−204	+ 30	+181	− 22	− 65	+145	+ 84	− 74
20	−147	−177	+173	−111	−458	+163	− 85	+110	+ 26	+ 32	+135	− 73
21	−361	−297	+199	− 96	−639	+239	−232	+312	+ 73	−145	+ 53	− 28
22	−459	−317	+251	−124	−846	+138	−167	+292	+ 55	−206	00	− 74
23	−659	−279	+429	− 95	−424	+ 78	−195	+350	+ 44	−184	− 28	− 90
24	−631	−323	+253	−333	−518	− 99	−195	+325	− 2	−263	−301	− 77
25	−573	−202	+ 36	−165	−396	−241	−212	+222	+ 28	−264	−291	−116
26	−346	−145	− 76	+ 3	−242	−183	−221	+123	+ 59	−260	−302	− 40
27	− 90	− 78	−190	+124	− 87	−235	−164	− 39	+ 63	−252	−330	− 88
28	+148	− 41	−121	+352	+216	−187	+ 38	−159	− 14	−292	− 31	− 29
29	+267	− 3	− 74	+265	+195	−166	+139	−266	−250	−260	+116	− 22
30	+346	+ 83	−135	+131	+175	−173	+251	−359	−271	−152	+ 11	− 37
31	+273	+177	−262	+107			+146	−510			+ 88	− 29

NOTE.—The following are the Declination-range for the last eight days of 1870: −55, +31, −35, +111, +215, +218, +316, +196.

Table II.—Comparison of Declination-range and Temperature-range Fluctuations for the Year 1872.

Day.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Dec.	Temp.	Dec	Temp.	Dec.	Temp	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.	Dec.	Temp.
1	-87	-60	+118	+97	-107	-262	+179	-340	-391	+583	-175	-113	-101	+205	+127	-74	+59	-9	-70	-143	+102	-104	+229	-165
2	-199	-15	+186	+80	-108	-248	+285	-225	-326	+343	-88	-4	-155	+126	+265	-170	-18	+5	+127	-195	+92	+81	+177	-171
3	-133	+41	+16	+65	-221	-109	+174	-238	-50	+0	-17	-57	-155	+415	+224	-315	-248	-51	+242	-74	-105	+66	+103	+83
4	-101	+84	-116	-42	-214	+13	+52	-106	+68	-182	+138	-137	-32	+570	+108	-165	-97	-60	+303	+158	+33	+185	+129	+167
5	-13	+32	-167	-55	-367	+210	+93	+16	+296	-276	+208	+56	-80	+331	+255	-145	+87	-122	+362	+298	-61	+171	+85	+207
6	-56	-31	-212	-74	-178	+144	+113	-29	+388	-310	+422	-40	+33	+50	+139	-118	+59	-73	+336	+219	-135	+50	-30	+279
7	+149	-113	-100	+58	-11	+149	+182	+34	+177	-287	+400	-222	+57	-205	+151	+40	+26	+6	+300	+257	-27	+8	+27	+32
8	+34	-65	+24	+120	+72	+153	+187	+243	+101	-332	+361	-252	+28	-275	+379	-142	-70	+0	+163	+93	+30	-104	-196	-97
9	-222	+66	+58	+30	+227	+170	+161	+210	-8	-319	+350	-429	+169	-140	+250	-234	-190	-34	+2	-65	+52	-85	-364	-23
10	-145	+132	+50	+19	+188	+244	+122	+388	-36	-148	+264	-443	+319	-120	+319	-329	-244	-146	-225	+4	+50	-59	-248	-45
11	-246	+182	+99	-56	+190	+239	-68	+421	+97	-204	+173	-354	+138	-148	+254	-343	-217	-104	-202	+63	+110	-123	-205	+125
12	-126	+148	+71	-92	+168	+230	-98	+390	+105	-239	-47	-77	+94	-286	-81	-109	-323	-111	-187	+191	-153	-69	-71	+221
13	+213	+108	+81	-109	+72	+210	-449	+455	+119	-45	-166	+193	+108	-440	-211	+34	-240	-40	-142	+319	-90	-95	-31	+145
14	+238	+98	+98	-98	+78	+148	-438	+261	+109	-43	-335	+307	+55	-256	-238	+85	-150	+23	-22	+359	+65	-248	-24	+175
15	+47	+145	+97	-60	+8	-21	-249	+92	+29	-86	-347	+467	+289	-225	-414	+253	-0	-25	-291	+268	-15	-244	-46	+53
16	+104	+157	-2	-96	-2	-88	-171	-133	-49	-108	-272	+437	+162	-6	-247	+254	+247	-143	-470	+7	+160	-216	-35	-69
17	+4	+147	-46	-3	+41	-275	+79	-352	-278	-104	-68	+310	+212	+132	-264	+277	+248	-125	-488	-93	+73	-19	+7	-26
18	+48	+85	-67	+86	-31	-265	+115	-297	-291	+19	+46	+329	+79	+122	-171	+357	+184	-79	-375	-139	+14	+133	-32	-106
19	+147	+34	-202	+116	+17	-181	+123	-223	-249	+196	+236	+209	-57	+413	+73	+153	+142	+7	-158	-269	+75	+262	+11	-92
20	+73	-4	-144	+226	+57	-116	+41	-148	-48	+393	+319	+45	+82	+385	-4	+68	+64	+214	+176	-279	-24	+229	+20	+35
21	+36	-91	-171	+168	+88	-131	+138	-80	+357	+393	+259	+55	-81	+468	-77	+67	+24	+269	+269	-177	-113	+164	+21	-38
22	-114	-36	-36	+185	+126	-157	+192	-124	+327	+316	+287	+5	-198	+453	-345	+212	+15	+113	+215	-171	-253	+80	+43	-89
23	-58	-115	+24	+108	+197	-91	+265	-89	+65	+383	+90	-180	-284	+225	-156	+203	+96	+68	+94	-77	-305	+157	-21	-168
24	+10	-168	+58	-3	+118	+136	+403	-106	+23	+286	+54	-242	-386	+66	+85	+98	+26	-111	-40	-17	-137	+125	+8	-221
25	+12	-170	+128	-73	+43	+430	+275	-127	-237	+160	-149	-398	-304	-61	+343	+54	-100	-151	-114	-82	+33	-59	-21	-191
26	+208	-206	-20	-152	-172	+351	+132	-186	-228	+43	-165	-471	-333	-77	+296	+57	-119	-104	-13	-73	+83	-67	-44	-147
27	+190	-122	-66	-145	-232	+146	-32	-37	-180	-65	-127	-277	-274	-102	+195	+24	-102	-103	+99	+53	+99	-205	-89	-92
28	+69	-126	-45	-242	-247	-88	-306	+159	-392	-133	-216	+40	-210	-88	+56	+49	-140	+45	+126	+127	+17	-174	-168	-95
29	+50	-90	-175	-186	-282	-417	-299	+457	-404	-195	-12	+32	-338	-5	+117	+40	-50	-141	+229	+46	+16	-138	-25	-15
30	-43	-78			+4	-323	-312	+760	-410	-51	-115	+88	+13	+37	+297	-182	+21	-112	+188	+69	+143	-89	+160	+39
31	-18	-42			+76	-356			-239	-72			+81	-31	+153	-120			+89	-91			+49	+67

Table III.—Algebraic Sums (as above) for the year 1871.

Declination pushed forward in days..	Months.											
	1, 2, 3.	2, 3, 4.	3, 4, 5.	4, 5, 6.	5, 6, 7.	6, 7, 8.	7, 8, 9.	8, 9, 10.	9, 10, 11.	10, 11, 12.	11, 12. 1 (1872).	12. 1, 2 (1872).
1												
2												
3												
4	20503	24721	34250	..	..	..	..	..	24274			
5	22442	24958	34471	..	..	..	..	..	25287			
6	23540	25060	34202	..	..	..	..	28977	25969	..	..	13374
7	23144	24563	..	29274	..	..	..	30562	26681	22478	..	13290
8	..	24060	..	29702	28432	..	..	31228	25968	22871	..	13608
9	..	..	..	30348	29366	..	..	31484	25192	23283	..	13574
10	..	..	..	30203	29281	28602	..	31008	..	23628	17145	13311
11	..	..	..	29252	29037	28767	26179	29859	..	23595	18079	
12	..	..	..	..	..	28929	27273	..	..	23090	18729	
13	..	..	..	..	..	27955	27561	..	..	..	18560	
14	..	..	..	..	..	..	27050					

Table IV.—Algebraical Sums (as above) for the year 1872.

Declination pushed forward in days	Months.									
	1, 2, 3.	2, 3, 4.	3, 4, 5.	4, 5, 6.	5, 6, 7.	6, 7, 8.	7, 8, 9.	8, 9, 10.	9, 10, 11.	10, 11, 12.
1										
2										
3	14442	..	24052							
4	14718	20890	24611	..	..	..	..	..	19624	
5	14200	21239	24845	..	..	..	..	..	19843	18889
6	..	20419	23646	29280	27123	..	..	20941	19694	19853
7	..	19072	23105	30777	29455	..	..	21405	19254	20200
8	..	..	..	32287	31133	..	..	21453	..	19758
9	..	..	..	32357	32247	30614	..	21205	..	18550
10	..	..	..	31002	31933	31442	..	21490		
11	..	..	..	..	..	32228	23791	21220		
12	..	..	..	..	..	32138	25237			
13	..	..	..	..	..	31522	25915			
14	..	..	..	..	..	..	25727			

7. The following are questions which suggest themselves with reference to the numbers of Table II:—

In the first place, do the inequalities of declination-range at all correspond with those of temperature-range? and, *secondly*, if so, what is the difference in phase between the two sets of inequalities?

I shall endeavour to reply to the last question first. In order to do so, let us take any three months of temperature-range, and try to find how far it is necessary to push forward the declination-range numbers in order to obtain the maximum amount of correspondence between them and those of the temperature-range for the three months under consideration. This will be denoted by a maximum algebraic sum of the two inequalities; in fine, we pursue precisely the same process as that adopted for ascertaining the difference of phase when comparing together the declination-ranges at Kew and Prague ("Proc. Roy. Soc.," vol. 29, page 316).

Now let us perform a number of such operations, taking various sets of three months each, so that the middles of the sets may correspond, as far as possible, to the middles of the various months between the beginning of 1871 and the end of 1872.

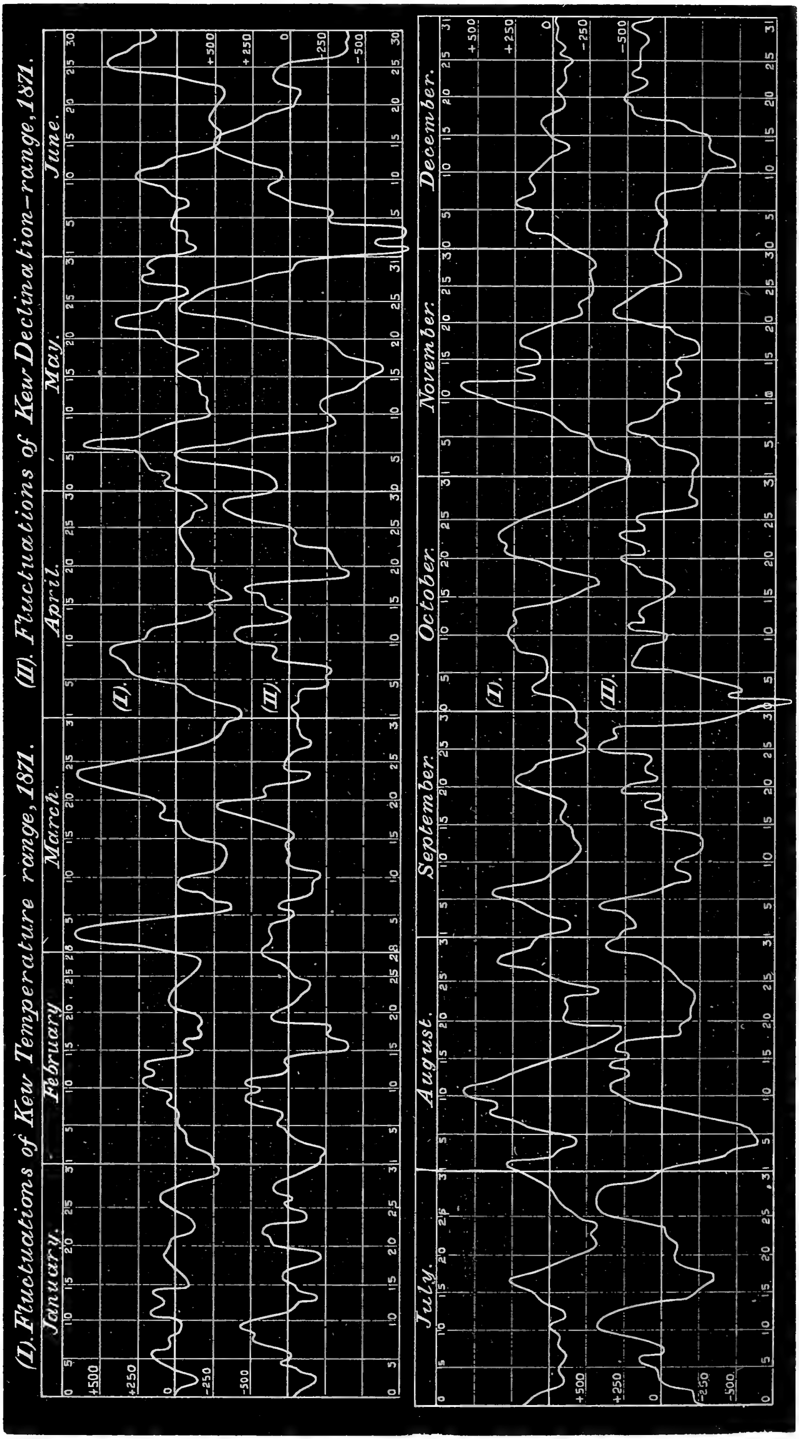
8. The results of this process are exhibited in Tables III and IV, in which, for shortness' sake, the various months of the year are numbered in order, instead of being named.

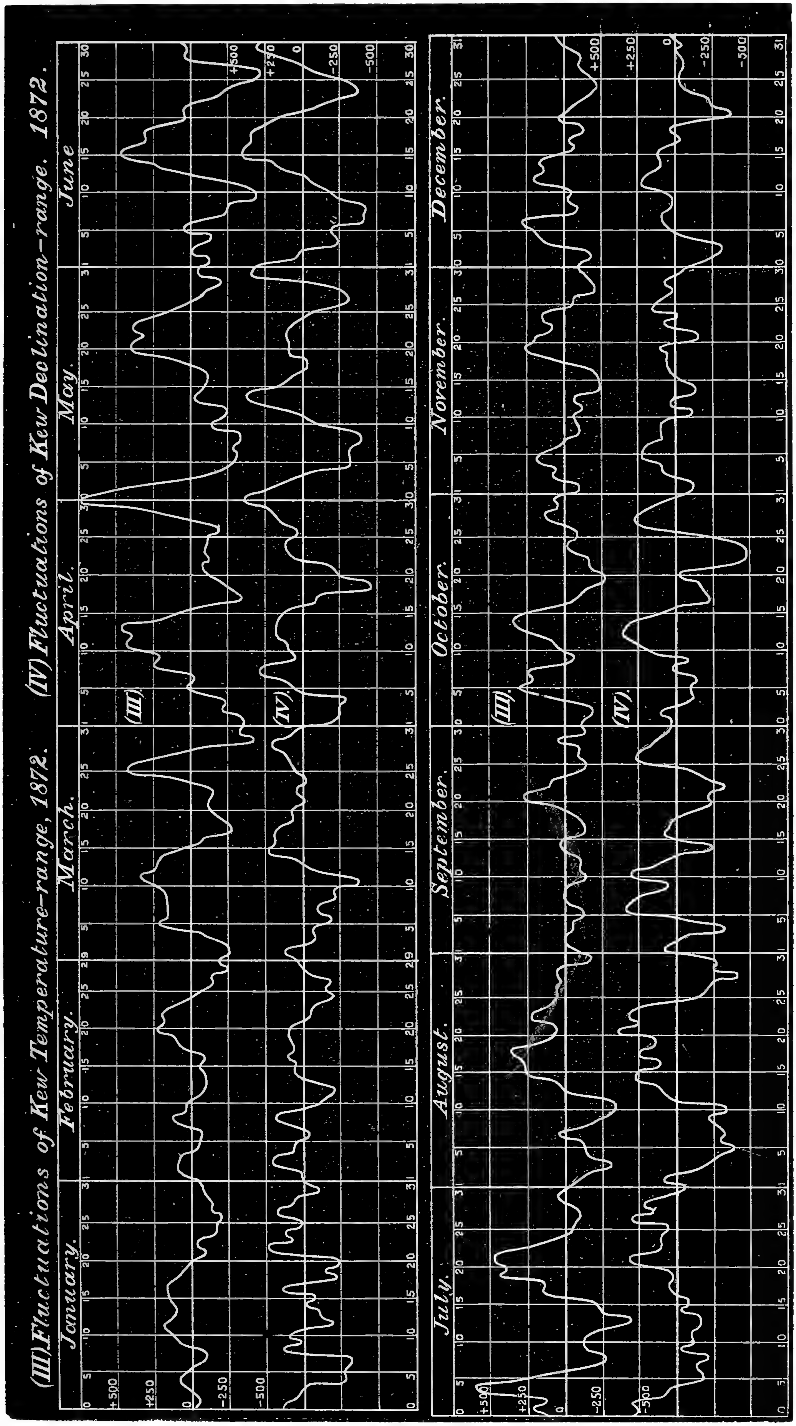
9. The results of Tables III and IV are conveniently embodied in the following table:—

Table V.—Showing by how many Days the Declination-range Fluctuation precedes the corresponding Temperature-range Fluctuation.

Corresponding to middle of month.	Precedence of Declination.		
	First year.	Second year.	Mean.
January	..	8	8
February	6	4	5
March	6	5	5·5
April	5	5	5
May	9	9	9
June	9	9	9
July	12	11	11·5
August	13	13	13
September	9	10	9·5
October	7	5	6
November	10	7	8·5
December	12	..	12

It thus appears that the precedence of declination is smallest about the equinoxes and greatest about the solstices, and it seems probable


(I). Fluctuations of Kew Temperature range, 1871.
(II). Fluctuations of Kew Declination-range, 1871.
January.
February
March.
April.
May.
June.
July.
August.
September.
October.
November.
December.
(I).
(II).
+500
+250
0
-250
-500


(III) Fluctuations of Kew Temperature-range, 1872.
(IV) Fluctuations of Kew Declination-range. 1872.
January.
February.
March.
April.
May.
June
July.
August.
September.
October.
November.
December.
(III).
(IV).
+500
+250
0
-250
-500

that were a considerable number of years so treated, more exact values exhibiting the law would be obtained. The law itself is sufficiently obvious in each of the two years now treated.

10. It has still to be ascertained to what extent the two fluctuations, when brought together so that similar phases coincide as nearly as possible, show any distinct resemblance to each other.

The evidence on this point is given by the diagrams which accompany this paper. These contain curves representing the continuous progress of the two sets of fluctuations for the years 1871 and 1872, these being portioned out into months. The temperature-range curve has a uniform time scale. The declination-range curve is pushed forward by a distance derived from the last column of Table V. Thus for January of each year it is pushed forward eight days, for February of each year five days, and so on. The consequence of this is that the declination-range scale, while constant for the various portions of the same month, yet varies slightly from one month to another.

An inspection of the curves will show that there is a considerable likeness between them. Perhaps this likeness is greater in the second than in the first year, but it must be borne in mind that 1871 was a year of great magnetic disturbance, and therefore unfavourable for such a comparison.

It would thus seem as if a comparison of magnetical and meteorological weather might be made a promising subject of inquiry, besides being one which may perhaps lead to results of practical importance.

Before concluding I beg to thank Messrs. William Dodgson and Alfred Nish for the assistance which they have rendered in this investigation.

March 16, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Pursuant to notice given at the last Meeting of the Society, H.R.H. the Duke of Edinburgh was proposed by the President, and seconded by the Treasurer, for election and immediate ballot. The ballot having been taken the Duke of Edinburgh was declared duly elected a Fellow of the Society.

The following Papers were read :—

I. "Sur les Centres de Courbure Principaux des Surfaces Homofocales du Second Ordre." By Lieut.-Colonel A. MANNHEIM, Professor in the École Polytechnique. Communicated by Dr. HIRST, F.R.S. Received March 4, 1882.

Dans la séance du 19 Janvier, 1882, j'ai eu l'honneur de communiquer à la Société Royale une note ayant pour objet de faire connaître quelques unes des liaisons qui existent entre les éléments de courbure des surfaces homofocales à une surface donnée et les éléments de cette surface.

Je me propose maintenant de démontrer quelques théorèmes relatifs aux centres de courbure principaux des surfaces homofocales, et de faire voir comment sont liés géométriquement les six centres de courbure principaux des trois surfaces homofocales qui passent par un même point.

Je vais prendre, pour point de départ, les expressions des rayons de courbure principaux auxquelles je suis arrivé dans ma précédente communication ; c'est le seul emprunt que je ferai à ce travail.

Je ne me suis pas astreint à conserver mes anciennes notations ; je définirai tout ce que j'emploierai, de telle sorte que le travail actuel peut se lire indépendamment du précédent.

Soient (E) et (O) deux ellipsoïdes homofocaux de centre o. Menons au point m de (E) la normale N à cette surface. Appelons (H′) et (H″) les hyperboloïdes homofocaux à (E) qui passent par m, menons aussi de ce point les normales N′, N″ à ces surfaces.

Les droites N′, N″ sont les axes de l'indicatrice de (E) en m, et les plans (N, N′), (N, N″) sont les plans des sections principales de (E) relatifs à ce point. Les six centres de courbure principaux des surfaces (E), (H′), (H″) sont μ_1, μ_2 sur N, μ'_1, μ'_2 sur N′, μ''_1, μ''_2 sur N″.

Circonscrivons à (O) un cône dont le sommet soit *m*. Les axes de ce cône sont N, N′, N″. Le plan (N, N′) est le plan d'une section principale de ce cône ; il coupe cette surface suivant deux génératrices qui font, avec N, un angle ω. Le plan de la courbe de contact de ce cône, c'est-à-dire le plan polaire de *m* par rapport à (O), rencontre N, N′, N″ aux points *l*, *l′*, *l″*.

En vertu de relations établies dans ma communication du 19 Janvier, on a :—

$$m\mu_1 = \frac{ml}{\cos^2 \omega}, \qquad m\mu'_1 = \frac{ml'}{\sin^2 \omega},$$

d'où

$$\frac{ml}{m\mu_1} + \frac{ml'_1}{m\mu'_1} = 1.$$

Lorsque l'on prend d'autres surfaces homofocales que (O), on a d'autres points, tels que *l*, *l′*, et si l'on considère *m l*, *m′ l′* comme coordonnées d'un certain point du plan (N, N′), le lieu de ce point, d'après l'équation précédente, est la droite μ_1, μ'_1.

Il résulte de là que :—

Les droites, telles que l l′, *enveloppent une parabole, elles déterminent sur* N *et* N′ *des segments proportionnels. Cette parabole touche* N *et* N′ *aux centres de courbure principaux* μ_1, μ'_1, *relatifs à la section principale* (N, N′) *des surfaces* (E) *et* (H′) *normales à* N *et* N′.

Ce que nous venons de dire pour le plan (N, N′) peut se répéter pour les plans (N, N″), (N′, N″) et, dans chacun de ces plans on a une parabole.

Les paraboles, qui sont dans les plans (N, N″), (N′, N″), touchent respectivement N et N′ aux centres de courbure μ_2 et μ'_2 des sections faites dans (E) et (H′) par ces deux plans, qui sont menés par N″.

La droite μ_2, μ'_2 *est alors l'axe de courbure* de la ligne d'intersection de* (E) *et de* (H′). Nous verrons tout à l'heure que cet axe de courbure est tangente à la parabole qui est dans le plan (N, N′).

Nous avons vu que les droites, telles que *l l′*, déterminent sur N et N′ des segments proportionnels. Il en est de même des droites telles que *l l″* relativement à N et N″ ; nous avons donc ce théorème :—

Les plans polaires d'un point m, *par rapport à des surfaces homofocales, déterminent sur les droites* N, N′, N″, *axes des cônes circonscrits à ces surfaces et dont le sommet est* m, *des segments proportionnels.*

* L'axe de courbure, relatif à un point *m* d'une courbe gauche, est la perpendiculaire élevée au plan osculateur en *m*, à partir du centre de courbure de la courbe en ce point. La connaissance de l'axe de courbure pour un point d'une courbe entraîne donc pour ce point la connaissance du plan osculateur et du centre de courbure de cette courbe.

Parmi ces plans polaires, il y a les plans (N, N′), (N, N″), (N′, N″) qui sont les plans tangents en m aux surfaces (E), (H′), (H″), et les plans principaux des surfaces homofocales, qui sont les plans polaires de m, par rapport à celles de ces surfaces qui sont infiniment aplaties.

L'enveloppe de ces plans polaires est alors une surface développable tangente à ces six plans. La trace de cette développable sur le plan (N, N′) est la parabole enveloppe des droites telles que $l\,l'$, cette développable, qui est tangente au plan (N, N′), étant coupée par ce plan suivant une parabole est alors du 4[e] degré. Nous avons donc ce théorème :

Les plans polaires d'un point m, *par rapport à des surfaces homofocales, enveloppent une surface* (D) *du* 4[e] *degré, qui est tangente aux plans principaux des surfaces homofocales, ainsi qu'aux plans principaux des cônes de sommet* m *circonscrits à ces surfaces.*

Comme les paraboles suivant lesquelles la surface (D) coupe les plans (N, N′), (N, N″), (N′, N″), sont les paraboles dont nous avons déjà parlé, on a ce théorème :

La développable (D), *enveloppe des plans polaires de* m, *touche les droites* N, N′, N″, *aux six centres de courbure principaux de* (E), (H′), (H″), *et touche les plans* (N N′), (N, N″), (N′, N″), *suivant les axes de courbure des courbes d'intersection de ces surfaces prises deux à deux.*

On voit bien maintenant pourquoi les axes de courbure de ces courbes sont tangentes aux paraboles, traces de (D), sur les plans (N, N′), (N, N″), (N′, N″).

Par N′, menons des plans tangents à (O). Ces plans touchent le cône de sommet m circonscrit à cette surface suivant les deux génératrices qui sont dans le plan de la section principale de ce cône, perpendiculaires à N′. De là résulte que, par rapport à (O), ce plan, qui n'est autre que le plan (N, N″), est le plan polaire de l'. De même le plan (N, N′) est le plan polaire de l'' par rapport à la même surface. Rapprochons indéfiniment (O) de l'ellipsoïde (E) et nous arrivons à ce théorème :

La normale en m *à l'une des surfaces homofocales a pour polaire, par rapport à cette surface, l'axe de courbures de la ligne d'intersection des deux autres surfaces homofocales qui passent en* m.

On retrouve aussi ce théorème connu :

Les centres de courbure principaux d'une surface du second ordre en m *sont les pôles du plan tangent en ce point à cette surface par rapport aux deux surfaces homofocales qui passent par* m.*

Appelons a, b, c les points où N perce les plans principaux des surfaces homofocales. De même, appelons a', b', c', a'', b'', c'' les points analogues pour N′ et N″. Puisque les plans principaux sont des plans

* Voir "Treatise on the Analytic Geometry of Three Dimensions." By George Salmon. 3rd edition. Page 151.

tangents à la développable (D) *les droites* aa', bb', cc', *sont tangentes à la parabole trace de* (D) *sur le plan* (N, N').

Comme cette parabole est tangente à N au centre de courbure μ_1, on voit que:

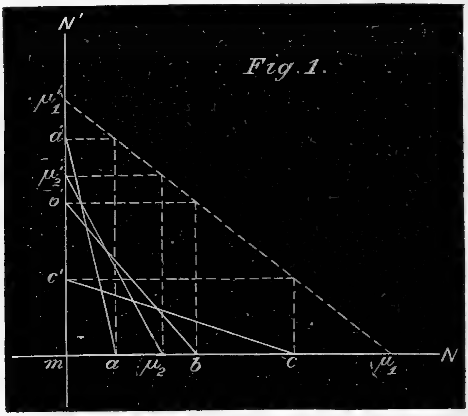
Le centre de courbure μ_1, *de la section faite dans* (E) *par le plan* (N, N'), *est placé sur* N, *par rapport à* a, b, c, *comme le point* m *est placé sur* N', *par rapport à* a', b', c'.

Ce que nous disons pour ce centre de courbure peut se répéter pour les autres. De là résultent, pour ces points, différentes constructions que je ne crois pas nécessaire de développer.

Des points l, l', l'', où l'un des plans polaires de m rencontre N, N', N'', élevons respectivement des plans perpendiculaires à ces normales. Ces trois plans se coupent en un point λ. Puisque les plans polaires de m déterminent sur N, N', N'' des segments proportionnels, nous voyons que:

Les points, tels que λ, *relatifs aux plans polaires de* m *par rapport aux surfaces homofocales, sont en ligne droite.*

Nous désignerons cette droite par Λ; on peut la construire en employant deux plans principaux des surfaces homofocales qui sont deux plans polaires particuliers de m.



Prenons le plan (N, N') pour plan de la figure 1. Marquons sur N et N' les points a, b, c, a', b', c' où ces droites rencontrent les plans principaux des surfaces homofocales. Sur N et N' nous avons les centres de courbure principaux μ_1, μ'_1.

D'après ce que nous avons vu, la parabole tangente à aa', bb', cc', N, N' touche ces dernières droites aux points μ_1, μ'_1. Les points a, a' sont alors les projections sur N et N' d'un point de la corde de contact $\mu_1\,\mu'_1$. De même pour b, b' et c, c'.

Pour avoir sur N le centre de courbure μ_2, nous devons prendre un point qui soit placé par rapport à a, b, c comme le point m est placé sur N″* par rapport à a'', b'', c''. Le point μ'_2 s'obtient de la même manière sur N′. Les points μ_2 et μ'_2 sont alors aussi les projections sur N et N′ d'un même point de la corde de contact μ_1 μ'_1.

La droite μ_2 μ'_2 est donc tangente à la parabole comme nous l'avions déjà trouvé.

Les segments ab, $a'b'$, sont les projections sur N et N′ d'un segment de μ_1 μ'_1, qui, lui même, est la projection sur le plan (N, N′) du segment de Λ, qui se projette sur N″ en a'' b''.

Ce segment de Λ rencontre le plan (N, N′) au point de μ_1 μ'_1 qui se projette sur N et N′ en μ_2 et μ'_2.

Ce que nous venons de trouver en considérant le plan (N, N′) peut se répéter pour les plans (N, N″), (N′, N″).

De tout cela résulte cette propriété qui établit une liaison très simple entre les six centres de courbure principaux de (E), (H′), (H″).

Trois surfaces homofocales du second ordre se coupent en un point m. *Les normales à ces surfaces en ce point sont* N, N′. N″. *Ces normales rencontrent les plans principaux des surfaces homofocales, la première en* a, b, c, *la deuxième en* a′, b′ c′, *et la troisième en* a″, b″, c″. *On élève respectivement de ces points des plans perpendiculaires à ces normales. Les plans issus des points* a, a′, a″ *se coupent en un certain point. On obtient de même un point pour* b, b′, b″ *et un troisième point pour* c, c′, c.″ *Ces trois points appartiennent à une même droite* Λ.

Les projections de Λ, *sur les plans déterminés par les normales* N, N′, N″, *prises deux à deux, rencontrent ces normales aux centres de courbure principaux des trois surfaces homofocales.*

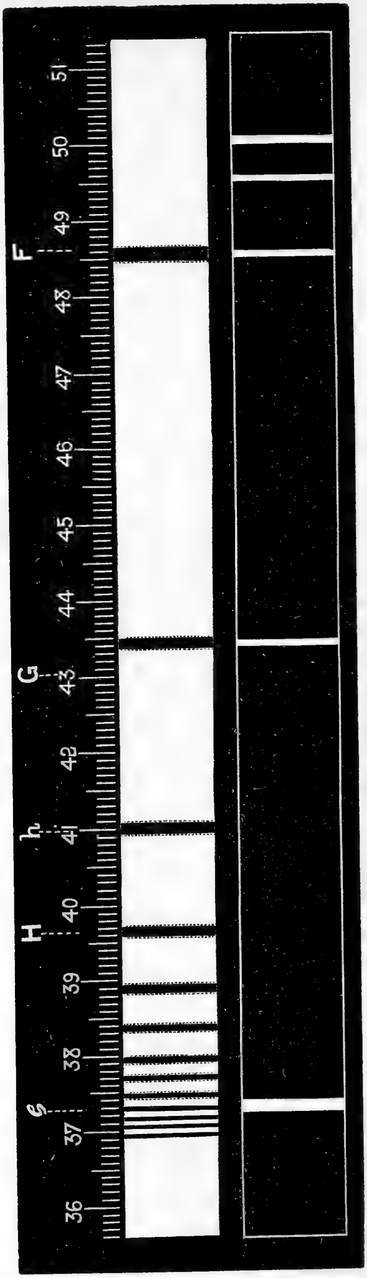
Ces centres de courbure sont alors aussi les projections sur les normales N, N′, N″, *des points où* Λ *perce les plans déterminés par ces normales prises deux à deux. La droite, qui joint les projections sur deux de ces normales du point où* Λ *perce le plan de ces droites, est l'axe de courbure de la ligne d'intersection des surfaces homofocales normales à ce plan.*

II. "Note on the Photographic Spectrum of the Great Nebula in Orion." By WILLIAM HUGGINS, D.C.L., LL.D., F.R.S. Received March 9, 1882.

Last evening (March 7) I succeeded in obtaining a photograph of the spectrum of the great nebula in Orion, extending from a little below F to beyond M in the ultra-violet.

The same spectroscope and special arrangements, attached to the 18-inch Cassegrain telescope with metallic speculum belonging to the

* N″ n'est pas sur la figure, ni les points a'', b'', c''.


51
50
49
F
48
47
46
45
44
G
43
42
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41
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ε
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36

Royal Society, were employed which have been described in my paper on "The Photographic Spectra of Stars." *

The exposure was limited by the coming up of clouds to forty-five minutes. The opening of the slit was made wider than during my work on the stars.

The photographic plate shows a spectrum of bright lines, and also a narrower continuous spectrum which I think must be due to stellar light. The bright stars forming the trapezium in the "fish's mouth" of the nebula were kept close to the side of the slit, so that the light from the adjacent brightest part of the nebula might enter the slit.

Outside this stronger continuous spectrum I suspect an exceedingly faint trace of a continuous spectrum. In the diagram which accompanies this paper the spectrum of bright lines only is shown, which is certainly due to the light of the nebula.

In my papers on the visible spectrum of the nebula in Orion, and other nebulæ,† I found four bright lines. The brightest line, wave-length 5005, is coincident with the less refrangible component of the double line which is strongest in the spectrum of nitrogen. The second line has a wave-length of 4957 on Ångström's scale. The other two lines are coincident with two lines of hydrogen, $H\beta$ or F, and $H\gamma$ near G.

In the photograph these lines which had been observed in the visible spectrum are faint, but can be satisfactorily recognised and measured. In addition to these known lines the photograph shows a relatively strong line in the ultra-violet, which has a wave-length 3730 or nearly so. The wide slit does not permit of quite the same accuracy of determination of position as was possible in the case of the spectra of stars. For the same reason I cannot be certain whether this new line is really single, or is double or multiple. In the diagram this line is represented broad to indicate its great relative intensity.

This line appears to correspond to ζ of the typical spectrum of white stars.‡ In these stars this line is less strong than the hydrogen line near G; but in the nebula it is much more intense than $H\gamma$. In the nebula the hydrogen lines F and $H\gamma$ are thin and defined, while in the white stars they are broad and winged at the edges. The typical spectrum has been added, for the sake of comparison, to the diagram.

I cannot say positively that the lines of hydrogen between $H\gamma$ and the line at 3730 are absent. If they exist in the spectrum of the nebula, they must be relatively very feeble. I suspect, indeed, some very faint lines at this part of the spectrum, and possibly beyond λ 3730, but I am not certain of their presence. I hope by longer ex-

* "Phil. Trans.," 1880, p. 672.

† *Ib.*, 1864, p. 437, and 1868, p. 540. Also "Proc. Roy. Soc.," vol. 14, p. 39, and vol. 20, p. 380.

‡ "Phil. Trans.," 1880, p. 677.

posures and with more sensitive plates, to obtain information on this and other points. It is, perhaps, not too much to hope that the further knowledge of the spectrum of the nebulæ afforded us by photography, may lead by the help of terrestrial experiments to more definite information as to the state of things existing in those bodies.

III. "On the Disappearance of some Spectral Lines and the Variations of Metallic Spectra due to Mixed Vapours." By G. D. LIVEING, M.A., F.R.S., Professor of Chemistry, and J. DEWAR, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received March 11, 1882.

The theory of spectral lines most commonly received is that the otions of the luminiferous ether producing them are not directly due to any motion of translation of the molecules of the emitting substance, but to relative motions of the parts of the same molecule, or in other words, to vibrations occurring within the molecules; and that the mutual action of the molecules, while it may give rise to irregular vibrations of the ether, affects the regular vibrations producing the lines only in an indirect manner, by converting part of the motions of translation into internal vibrations. On this theory the spectral lines which any given substance can readily take up will in general be limited to a certain number of fundamental lines and a number of others harmonically related to them, though not necessarily simple harmonics of the fundamental lines. And variations of temperature, by altering the rapidity and the violence of the action of one molecule on another, will alter the intensities of the several vibrations, but not their periods, unless the violence should extend to the disintegration of the molecules, which would be equivalent to the formation of new molecules with new fundamental periods of vibration. In view of this theory, the observations on the spectrum of magnesium have a special interest, because from the close analogy of magnesium to zinc and cadmium, it is inferred that the molecules of magnesium vapour are chemical atoms of that substance, that is to say, they pass apparently undivided through all the chemical changes to which magnesium may be subjected; and it seems reasonable to suppose that any subdivision of the chemical atoms could not fail in this case to be attended with a change of chemical qualities, which, in the presence of other elements, would give rise to new compounds. No such new compounds have in fact been detected. We have already described in detail the differences between the spectra of magnesium as seen in the flame of the burning metal, the electric arc, and the spark discharge, and we have now some further observations upon them to place before the Society, which are confirmatory of the received theory.

We have observed the spectrum of a block of magnesia, rendered incandescent by an oxyhydrogen jet. In the visible part of this spectrum we found no discontinuity, no lines bright or dark (except the inevitable D lines), no sign of the blue channelled spectrum of magnesia. Drs. Huggins and Reynolds ("Proc. Roy. Soc.," vol. 18, pp. 547, 551) have recorded the appearance of the *b* group under these circumstances, but we failed to get sight of it. In the ultra-violet region photographs still show a continuous spectrum, extending far beyond the limit of the solar spectrum, in fact as far as we have hitherto observed any lines of magnesium to occur, but on this continuous spectrum one line, and only one, comes out, which is the strongest line of burning magnesium and of the arc spectrum, at wave-length 2852 (2850 Cornu). This line shows sometimes bright, sometimes reversed, against the continuous background. In this case, where the appearance of the lines depends on their relative brightness, as compared with the continuous spectrum, there is no advantage, so far as the visible rays are concerned, in the photographic method over that of observation by the eye; there may be a disadvantage, as the photograph presents only the mean result of a certain time. But where the faint lines of a discontinuous spectrum are in question the photographic method has the advantage, for when the vibrations are too feeble to produce any sensible impression on the retina, they may yet, by integration of their effects during a lengthened exposure, produce a definite effect on the photographic plate. In general we have only exposed our plates for such times as would give us the best defined images, so that very faint lines are not developed in them; but by using a prolonged exposure we find that in many cases the disappearance of lines from the arc or spark is more apparent than real, and is attributable to a variation of intensity, not to an absolute cessation of the vibrations corresponding to the evanescent lines. Thus of the quadruple group between wave-lengths 2789 and 2802 in the spark spectrum of magnesium only the stronger two lines are usually seen in photographs of the arc with short exposure, but the whole four produce their impressions on the plate if sufficient time be given. Again, the triplet in the arc spectrum at wave-length about 2942—2937·5 is not usually seen in the spectrum of the spark, but when the plate has had a lengthened exposure the strongest two lines of this triplet make their appearance in the spectrum of the spark. Even the triplet near M, so strong in the flame of burning magnesium, but not before recognised either in the arc or spark in photographs taken with short exposure,* comes out in plates of the spectrum of the Spottiswoode induction spark (if we may give this name to the method of stimulating the induction coil by the intermittent current of a

* Dr. Huggins has informed us that his old photographs of the magnesium spark taken with an induction coil in the ordinary way show this triplet distinctly.

magneto-electric machine, see "Proc. Roy. Soc.," vol. 30, p. 175) between magnesium electrodes which have had four or five minutes' exposure. These observations tend to confirm the theoretical view that alterations of temperature cannot put a stop to any of the fundamental vibrations of a molecule; at the same time we cannot be sure that the impulses communicated by an electric discharge may not be in some respects different from those resulting from mere increment of temperature.

There is, however, a further point for consideration, which is, how far the presence of a mixture of molecules of different elements affects the respective vibrations. This is a condition which obtains in most or all of our observations of the arc in crucibles, as well as in the solar atmosphere, so that it is important to see if any effects can be traced to such a condition of matter. Indeed, in order to arrive at any probable explanation of the variations observed in the spectra of sun-spots and of the chromosphere, we require to study the phenomena produced by such mixtures of vapours as exist in our crucibles, and not merely the spectra produced by the isolated elements, either in arc, spark, or flame.

It is only on some such supposition as that above suggested that we can account for the absorption lines produced by admixtures of magnesium with sodium and potassium respectively ("Proc. Roy. Soc.," vol. 27, p. 353); and it is possible that the very remarkable effect of hydrogen in producing the reversal of chromium lines (*ib.*, vol. 32, p. 405) and of other lines (*ib.*, vol. 28, p. 472) is a result of analogous action. We have more particularly observed the effect of a current of hydrogen on the iron lines at wave-lengths 4918, 4919·7, and 4923. These lines, as seen in the arc in a magnesia crucible, usually have about the same relative strengths as are shown in Ångström's map of the solar spectrum; Thalén gives their intensities as 2, 1, 3 respectively. They are all developed simultaneously when iron is dropped into the crucible, the first being sometimes reversed, the second frequently reversed for some time, the third much strengthened but not reversed. After a time these effects die out, but if now a *very gentle* current of hydrogen is led in through one of the carbons perforated for the purpose, the line at 4919·7 is again strongly reversed, that at 4918 expanded, while that at 4923 becomes very bright but remains sharply defined. These effects of the hydrogen were observed several times. In all cases the line at wave-length 4923 seemed to maintain about the same relative strength compared with the other two lines, and never showed any variation at all corresponding to the prominence it holds in Young's catalogue of chromospheric lines, where it has a frequency of forty, while that at 4918 has only half that frequency, and the strongest line of the three does not figure at all.*

* Mr. Lockyer's figure ("Proc. Roy. Soc.," vol. 32, p. 205) accompanying his

Some further observations on this group of lines are contained in the sequel.

The effects of mixtures of metallic vapours in developing bright lines are equally marked, and in general more easily observed. We have before noticed ("Proc. Roy. Soc.," vol. 30, p. 97) "that certain lines of metals present in the crucible are only seen, or come out with especial brilliance, when some other metal is introduced. This is the case with some groups of calcium lines which are not seen, or barely visible, in the arc in a lime crucible, and come out with great brilliance on the introduction of a fragment of iron, but are not developed by other metals such as tin." Effects of this kind are most frequent in the case of metals which produce a large number of lines. They are specially noticeable in the case of nickel and titanium. Both these metals produce many lines, but a comparatively large quantity of nickel may be introduced into a crucible of magnesia, through which the arc of a powerful Siemens dynamo-electric machine is passing, without the lines of nickel being strongly developed; they show steadily as sharp but not specially bright lines; but after several other metals—iron, chromium, &c.—have been put in in succession, the nickel lines frequently come out with great brilliance and considerably expanded, and remain so for a long time. The titanium lines are generally very persistent when that metal (as cyanide or oxide) has been introduced into the crucible, but are subject to continual variations of intensity; sometimes they are twinkling, at other times steady; but they can frequently be brought out with great brilliance by dropping in iron or other metals. In such cases the metals put into the arc can hardly be supposed to increase the resistance or the temperature, but they may assist the volatilisation of each other, and may also act by reduction, and so by increasing the incandescent mass strengthen the weaker lines. Chlorides, however, which seem to have the effect of helping the volatilisation and diminishing the resistance so that the arc can be drawn out to a greater length, usually sweep out the fainter lines.

In many cases when a fragment of a metal is dropped into the crucible brilliant lines, hitherto unrecorded, come out for a short time and quickly die out. It is hardly possible in such cases to say without prolonged observations whether these lines belong to the newly introduced metal or to some of those previously put in and developed by the presence of the new metal. How much remains to be done in the study of these lines, and how much light this may throw on the phenomena of the solar lines, will be seen from the following account of our observations of some very small portions of the spectrum of the

paper on the spectra of sun-spots showing "what happens with regard to three adjacent iron lines under different solar and terrestrial conditions," is at variance with our observations, in so far as the line at 4923 is represented as absent from the arc.

arc in a magnesia crucible. The portions selected are of special interest, because in these regions a remarkable outburst of broad Fraunhofer lines, not usually visible, is recorded by the Astronomer Royal as having occurred in a sun-spot ("Monthly Not. Ast. Soc.," 1881).

Fig. 1 shows the principal (not all the) lines which were in the same field of view when the spectrum of the 4th order produced by a Rutherford grating (17,296 lines to the inch) was observed, the light being that of the arc of a Siemens machine in a magnesia crucible. A small piece of copper was first put in and then some nickel, and by the lines of these metals the portion of the spectrum under examination was identified. The iron lines were as usual also present. The symbols affixed to the several lines show those which came out when the metals indicated were introduced. Thus, when chromium was dropped in, a very brilliant line came out near the middle of the field, a little below the iron line wave-length 5090·4; titanium cyanide brought out a line at about wave-length 5086, cobalt one at 5094, uranic oxide one at 5087, and cerium (which may have contained lanthanum and didymium) a number of lines. These lines were very bright for a second or two, and soon became much less brilliant, but were revived when more of the metal was put in. Lead brought out a very evanescent diffuse band represented in the figure by dotted lines. The distances of the several lines from the extreme nickel lines were measured hastily by a micrometer, and are here reproduced to scale. One line at wave-length 5096, though constantly present, did not seem to be affected by any of the metals introduced. An iron line is indicated on Ångström's map at this place, but the introduction of iron, which expanded the neighbouring line at wave-length 5097·3, had no effect on it. It is remarkable that this region in Ångström's normal solar spectrum is particularly bare of lines, though Vogel gives several faint lines between those marked by Ångström. It is, however, a region in which many lines have been observed in sun-spots (Greenwich Spectroscopic and Photographic Results, 1880), and the most prominent of these lines seem to correspond to lines developed by cerium, chromium, and cobalt, though more exact measures than we were able to take at the times that those observations were made are needed in order to establish an exact coincidence.

Fig. 2 represents the lines brought out in a similar way in another short portion of the spectrum, which is also remarkably bare of lines in the solar spectrum.

Fig. 3 shows lines brought out in another place by the several metals indicated. Other lines were visible in this region but were not specially developed by the metals introduced.

The line at wave-length 4923, which occurs so often in the chromo-

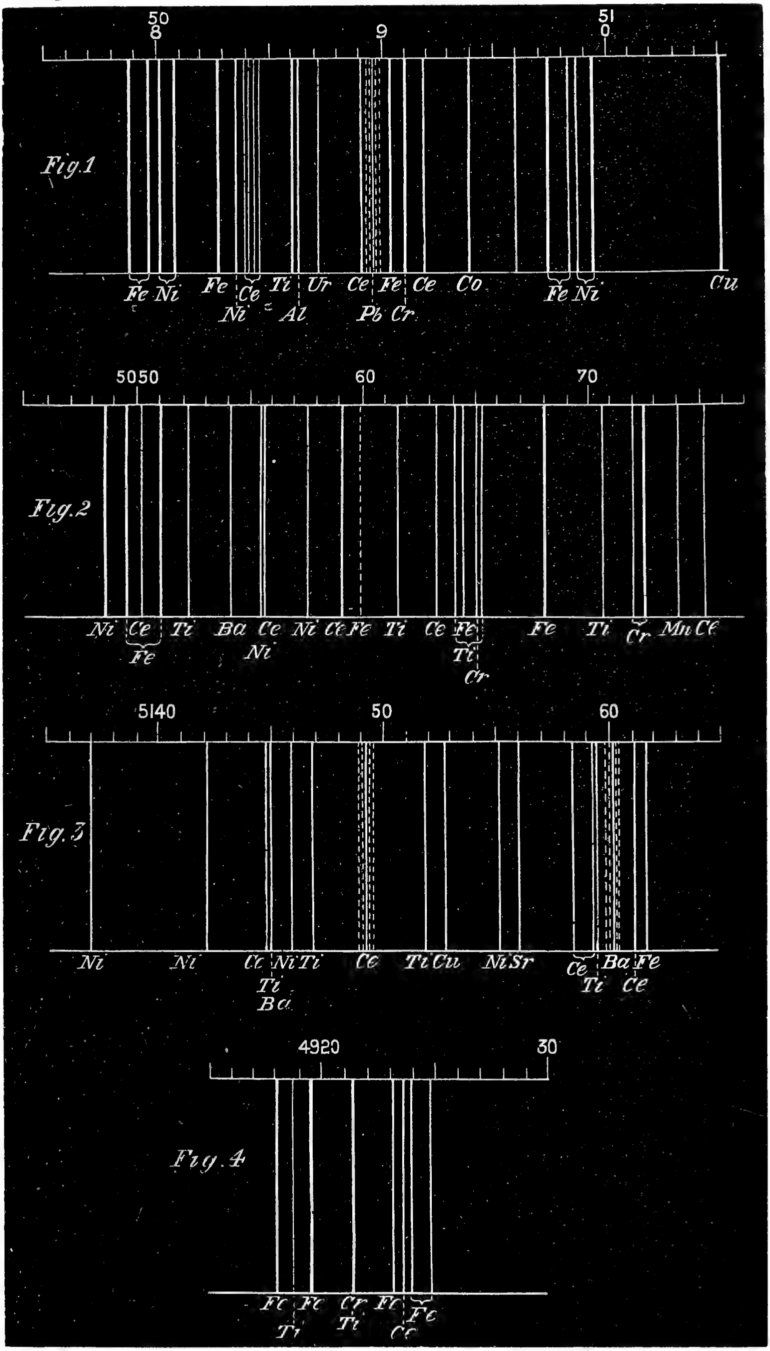


Fig. 1
50 8
9
51 0
Fe Ni Fe Ce Ti Ur Ce Fe Ce Co Fe Ni Cu
Ni Al Pb Cr
Fig. 2
5050
60
70
Ni Ce Ti Ba Ce Ni Ce Fe Ti Ce Fe Fe Ti Cr Mn Ce
Fe Ni Ti Cr
Fig. 3
5140
50
60
Ni Ni Ce Ni Ti Ce Ti Cu Ni Sr Ce Ba Fe
Ti Ti Ce
Ba
Fig. 4
4920
30
Fe Fe Cr Fe Fe
Ti Ti Ce

sphere, according to Young and Tacchini, and is assumed to be due to iron, is so near to lines which come out in our crucibles on the introduction of other metals, that we cannot help feeling some doubt as to its absolute identification with the iron line; the more so as in Young's catalogue bright lines are sometimes assigned to two metals, of which the real lines differ by nearly a unit of Ångström's scale. This is the case, for example, with the line at wave-length 5017·6, which is ascribed to iron and nickel. And where lines are broadened, as in sun-spots, the identification with either of two very close lines becomes very difficult.

Fig. 4 shows the lines which come out in the neighbourhood of wave-length 4923. A pair of lines are developed by iron close to this line, and a very bright but evanescent line comes out at about 4923·5, on the introduction of cerium. This is an exceedingly brilliant line for the time, and might easily be mistaken for the iron line unless examined under high dispersion, and it seems to show that metallic cerium is readily volatile under these conditions. The iron line at 4923 seems to disappear on the addition of titanium, which, on the other hand, brings out the lines marked titanium in the figure. Nickel brings out the cerium line strongly. The line which comes out at 4921·3 on the addition of chromium and titanium is most likely the line seen by Young in the chromosphere thirty times, which up to the present time has not been recognised as due to any element but sulphur.

Both the nickel line at 5016·5 and the adjacent iron line at 5017·5 are seen in the arc in our crucibles, but the nickel line is much the stronger and more persistent. Cerium when put into the crucible brightens the titanium lines, as well as the line at 5017·5. An alloy of manganese, iron, and titanium had the effect of making the nickel line broad and diffuse, without strengthening the 5017·5 line.

These are but samples of the large amount of work which remains to be done before we can pronounce that any of the solar lines are not due to terrestrial elements, or can draw any safe inferences from observed variations in their relative strengths or apparent coincidences; and no real scientific advance can be made by attempting generalizations with the knowledge which we at present possess.

March 23, 1882.

THE PRESIDENT in the Chair.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read :—

I. "On the Constituent of the Atmosphere that Absorbs Radiant Heat. II." By S. A. HILL, Meteorological Reporter, North-West Provinces and Oudh. Communicated by General STRACHEY, R.E., C.S.I., F.R.S. Received March 10, 1882.

General Strachey has suggested to me that with the data given in my first paper we may arrive at a numerical relation between the absorptive powers of dry air and aqueous vapour, instead of being content with merely showing that vapour is by far the most active constituent of the atmosphere in this respect. The following calculations, worked out on the lines suggested by him, indicate that the dry air has a small and, as far as we can judge, invariable effect in the way of absorption, while the effect of water vapour is large and variable. In other words, the air probably exercises a feeble absorption over the whole range of the spectrum, while the absorption due to water vapour is selective, and probably varies in amount with the nature of the radiation from day to day.

Starting with Pouillet's formula $r = R \times p^e$, where e stands for the atmospheric thickness and p for the fraction of the total radiation that would penetrate vertically through an atmosphere of unit thickness, we may take p to be made up of two factors, α and β, one of which represents the diathermancy of the dry air and the other that of vapour. The masses of dry air and water vapour traversed by the rays will be respectively proportional, though not in the same ratio, to the barometric pressure* and the vapour tension. Taking the length of an oblique ray through any atmospheric stratum to be proportional to sec z, we thus arrive at the formula

$$\log r = \log R + b \sec z \log \alpha + f \sec z \log \beta,$$

in which α and β stand for the fractions of the total heat transmitted through atmospheres composed respectively of dry air and aqueous

* That is to say, *approximately* proportional to the total pressure. It will not do to deduct the vapour tension from the total pressure, because the vapour thins out as we ascend much more rapidly than the air does.

vapour, and which, with the law of vertical distribution defined by the simultaneous observations at Mussooree and Dehra, would each produce a pressure equal to one inch of mercury.

From the observations of the 12th November, 1879, given at page 218 of my previous paper, we get the following equations:—

Mussooree.... $23{\cdot}533 \times 2{\cdot}304 \log \alpha + {\cdot}221 \times 2{\cdot}304 \log \beta = -{\cdot}09463$,
Dehra....... $27{\cdot}832 \times 2{\cdot}292 \log \alpha + {\cdot}375 \times 2{\cdot}292 \log \beta = -{\cdot}14233$;

and from the observations of the 14th we get:—

Mussooree... $23{\cdot}529 \times 2{\cdot}339 \log \alpha + {\cdot}183 \times 2{\cdot}339 \log \beta = -{\cdot}102293$,
Dehra...... $27{\cdot}825 \times 2{\cdot}330 \log \alpha + {\cdot}302 \times 2{\cdot}330 \log \beta = -{\cdot}151972$.

These give the following results:—

Date.	α.	β.	$1-\alpha$.	$1-\beta$.
12th........	·99856	·76030	·00144	·23970
14th........	·99855	·69536	·00145	·30464

The absorption due to dry air of one inch pressure seems therefore to be almost invariable and equal to only ·1445 per cent. of the total radiation—a quantity that could hardly be measured in laboratory experiments; while that due to water vapour of equal pressure varies between 24 and 30 per cent. (perhaps between much wider limits) and is equal, on the mean of the two days' observations, to 27·217 per cent. In an atmosphere of dry air at 30 inches pressure the absorption would be $1-\alpha^{30}$, or about $4\frac{1}{4}$ per cent. of the total radiation. The fraction of the total heat that is absorbed by dry air, though in most cases very small in comparison with that absorbed by the vapour, seems therefore to be an appreciable quantity, and, if the tension of vapour at sea-level were only $\frac{1}{7}$ of an inch or less, the dry air would have the greater effect of the two.

Since the quantities of air (Q) and vapour (Q_1) in a vertical column of given sectional area are in the ratio $\frac{Q}{Q_1} = \frac{b}{f} \times \frac{\sigma}{\sigma_1} \times \frac{C}{C_1}$, where C and C_1 are the constants of the logarithmic formulæ for vertical distribution, the absorptive powers for equal masses of the two gases will be in the ratio $\frac{{\cdot}1445}{27{\cdot}217} \times \frac{5}{8} \times \frac{26106}{66218} = \frac{1}{764{\cdot}4}$. Water vapour has, therefore, 764·4 times the absorptive power possessed by air for the kind of radiation emitted from the sun on the 12th and 14th November, 1879. As a very large proportion of the total solar radiation is luminous, and since water, both in the liquid and in the gaseous state, transmits the greater part of the luminous radiation, the relative diathermancy of dry air for radiant energy proceeding from sources at a lower temperature must be very much greater still.

I regret that, up to the present, I have been unable to procure a record of any other actinometrical observations that would serve to test the correctness of these results.

II. "On the Influence of Coal-dust in Colliery Explosions. No. IV." By W. Galloway. Communicated by Robert H. Scott, F.R.S. Received December 29, 1881.

In the concluding pages of No. III paper, now in the hands of the Royal Society, I described an apparatus the essential parts of which consist of a wooden gallery about 126 feet long by 2 feet square, and a sheet iron cylinder about 6 feet long by 2 feet in diameter; and, at the same time, I gave a short general account of the experiments that had been made with it up to that date, intending to resume the subject on some future occasion. It will be remembered that the experiment was made by mixing together and igniting a small quantity of fire-damp and air in the sheet iron cylinder called the "explosion chamber"; that the resulting explosion burst through a paper diaphragm which separated the explosion chamber from the wooden gallery and created an air-wave; that the air-wave in passing through the gallery swept up coal-dust from the floor and from certain shelves placed at given points in it; and, lastly, that the flame of the original fire-damp explosion traversed the cloud of coal-dust and air to a greater or less distance from the origin.

During the warm dry weather prevailing between the 14th and 21st of July last, I made sixty-three further experiments, which for convenience may be separated into the three following well-defined groups.

I. Fifteen to ascertain how far the flame of the mixture of fire-damp and air contained in the explosion chamber would extend along the wooden gallery in the absence of every trace of coal-dust.

II. Thirty-eight to ascertain how far the flame produced in the same manner and under the same conditions as in the preceding case would extend into a cloud of coal-dust and pure air, created by the action of the air-wave in its passage through the wooden gallery.

III. Ten to ascertain the effects due to the explosion of small heaps of blasting powder placed at given points in the wooden gallery, all the other conditions being exactly the same as in the last case.

In each experiment the fire-damp was carefully and accurately measured by water displacement in a special cylinder called the measuring cylinder in the two preceding papers. No fire-damp could enter any part of the apparatus without first passing through the measuring cylinder, and being thence transferred into the explosion chamber. As has been previously stated, also the explosion chamber was separated from the wooden gallery by certain sheets of paper interposed between them in the form of a diaphragm. None but sheets without visible flaws were employed for this purpose, and they were inserted in the joint between the wooden gallery and the explosion chamber in such a way that their edges projected into the open air all round about. Seven minutes or so elapsed from the time the fire-damp was begun to be transferred into the explosion chamber until its mixture with air was ignited. The largest quantity of fire-damp employed in any one of the sixty-three experiments was 1·876, or say, 2 cubic feet, and if even one-half of this quantity had escaped there could have been no explosion, as the mixture remaining in the explosion chamber would not have been inflammable. Admitting, however, for the sake of argument, that, in every case, one cubic foot of fire-damp passed through each sheet of paper in the diaphragm in succession and found its way into the gallery, then its rate of escape would be, say, one-seventh of a cubic foot per minute. But, during the whole time the first forty-two experiments were in progress, there was a current of fresh air amounting to upwards of 1,000 cubic feet per minute constantly passing into the gallery immediately behind the diaphragm and traversing it towards its open end. Therefore, the greatest amount of fire-damp which the gallery could possibly have contained at any moment before one of these explosions was effected, even in the extreme case I have imagined, and with the further supposition that all the doors were shut, was about one-fourteenth part of a cubic foot, giving a mixture of one of gas to seven thousand of air, a proportion which is obviously far too small to be of the least practical account.

It appears necessary to give the foregoing explanation, inasmuch as, in a report on some experiments made with dust from Seaham colliery,* Professor Abel has made the following remarks regarding the experiments conducted with the smaller apparatus described to the Royal Society in 1879, and whatever applies to those experiments in this respect, applies with equal force to the present ones, which are nothing more than their continuation on a larger scale. At page 5, Professor Abel says,—" The apparatus devised by Mr. Galloway for the latter experiments was very ingenious, but it appears open to question whether small quantities of fire-damp did not find their way before the explosion from that part of the apparatus where the gas-mixture was prepared and fired into the channel where the coal-dust was raised, and into which the flame of the explosion was projected."

The coal-dust employed in this series of experiments came from the

* Report on the result of experiments made with the samples of dust collected at Seaham Colliery in compliance with the request of the Secretary of State for the Home Department, conveyed by a letter dated November 4, 1880. By F. A. Abel, C.B., F.R.S., &c.

same source as that used in most of the former ones. It had been produced in the operation of grinding coal for coke-making purposes, and had floated in the air and been deposited in a still atmosphere within the building containing the machinery. I could not obtain the results described in my previous papers, and in the present one, with dust taken from screens, or from the roadways of mines; for, on the one hand, the dust from screens seems to have lost its finest particles before being deposited; and, on the other hand, the feeble nature of my explosion prevented me from attempting to perform the winnowing operation to which I imagine the dust in mines is subjected before it is required to propagate the flame of an explosion.

It is an indispensable condition that the dust be dry, and I have found also that the best experimental results can only be obtained in fine dry weather. For instance, on the 20th of July, when it was warm and dry, I succeeded in producing flames of coal-dust and pure air varying in length from 108 to 147 feet; but on the 22nd, only two days afterwards, when it rained occasionally, and the air contained very finely divided moisture in the form of a light and hardly perceptible mist, I could not produce a flame even 36 feet long.

In making the series of experiments corresponding to the ones we are now discussing, which were described in No. II paper, I found that when the gallery was air-tight, or nearly so, the flame could not be propagated further than 30 or 40 feet from the origin; whereas, when the seams between the boards were open, the flame travelled 80 or 90 feet under the same conditions as before. The dry weather which had prevailed before the 14th of July last had dried up the timber of which the gallery was formed to such an extent as to produce twelve open seams in it longitudinally, varying from $\frac{1}{8}''$ to $\frac{1}{4}''$ wide; and it was recognised after the seventeenth experiment had been made, that this circumstance allowed the force of the fire-damp explosion to be dissipated, without forming an air-wave of sufficient energy to raise the coal-dust in the gallery. Accordingly, strips of wood were nailed along the seams on the top, on the doors, and on the back, while some of the succeeding experiments were in progress; strips of canvas were nailed along the seams on the floor; the spaces between the ends of the sections were carefully closed, and canvas was nailed along the joints between the doors and the gallery, with the object of making it as air-tight as possible everywhere. This operation was completed as far as the end of the sixth section, when the thirty-eighth experiment was made. The experience in this case was that the more air-tight the gallery could be made the better were the results.

When the twenty-eighth experiment was made, it first became evident that the gas and air in the explosion chamber had not been sufficiently well mixed in the preceding experiments to produce the best possible results by their explosion. Accordingly, in all the succeeding experiments the driving wheel was turned rapidly 200 times instead of 100 times as before, the attendants relieving each other at the work, and, thereafter, the results were much more uniform, and, consequently, more satisfactory.

It will be recollected from the account given in No. III paper, that the gallery consists of seven sections, and that each section has a door 18 feet long by 2 feet 3 inches wide, which constitutes one of its sides when it is closed (see sections *a* and *b*, fig. 3). When all the doors are open the gallery has only three sides—namely, top, bottom, and back, and its interior is exposed to view from one end to the other. The doors then stand out horizontally on a level with the top to which they are hinged, while their free edges are supported on suitable props. The table given below shows how many doors were shut, and how many were open when each experiment was made, the shut ones being, of course, those nearest the explosion chamber. In one or two experiments, however, there were three doors next the explosion chamber closed, the following three open, and the last one shut. This was the case, for example, in the sixty-third experiment. There is no provision in the table for showing this arrangement, and as the flame did not, on any of these occasions, extend to the last section, it was not considered worthy of a special column. Each of the seven sections contained coal-dust in the cases referred to, and that is the reason why they are all represented in the table.

There were sets of three shelves, one above the other, placed transversely in the gallery at the following points, measured from the diaphragm towards the open end: 10 feet, 21 feet, 32 feet 6 inches, 42 feet, 56 feet, 65 feet, 76 feet 4 inches, 87 feet, 96 feet 8 inches, 107 feet, and 117 feet 6 inches. The spaces between the shelves of each set, and between the highest and lowest shelf and the top and bottom of the gallery, were intended to have an approximately equal area. The shelves were about 6 inches wide by $\frac{3}{4}$ inch thick.

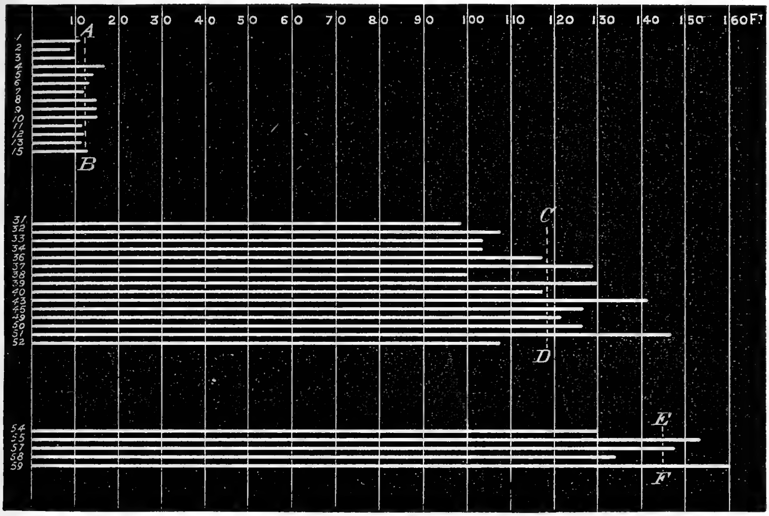
Those heaps of powder referred to in the table, whose distances from the diaphragm correspond to the position of certain of the sets of shelves, were in these instances placed on the top shelf, the others were laid on the floor.

After each experiment the coal-dust was entirely swept out and replaced by fresh dust, except in one or two cases which are specially mentioned in the table.

The diaphragm usually consisted of six single sheets of newspaper, but the exceptions are shown in the table. Where a note of interrogation occurs the number of sheets may be taken as six, although the real number was omitted in taking notes at the time.

Fig. 1 shows the length of flame (measured from the diaphragm) obtained in the principal explosion of each group.

FIG. 1.



I. The average length of fourteen fire-damp flames (12 feet 8 inches) is shown by the dotted line AB.*

II. The average length of fifteen flames of coal-dust and pure air (118 feet 6 inches) is shown by the line CD.

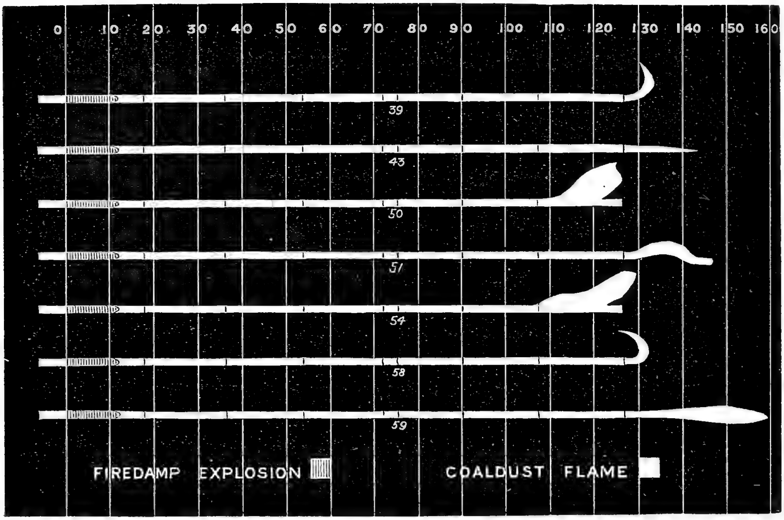
III. The average length of five flames of coal-dust and pure air, augmented by the explosion of small heaps of gunpowder (145 feet), is shown by the line EF.

All the experiments between the fifteenth and thirty-first are omitted, as they were made while the apparatus was in an imperfect condition.

In fig. 2 the apparatus is reproduced on a very small scale, so as to show its whole length, as well as the appearances presented by some of the more remarkable flames as they issued from its side, or end. The part which represents the explosion chamber is on the left hand side of the zero line, and the seven sections of the wooden gallery are on its right hand side. The form of the flames was sketched at the instant of their occurrence, with the exception of No. 59, which is correct as to length, and approximately correct as to its other dimensions, but was not sketched until afterwards. The average length of fire-damp flame obtained in the first fifteen experiments is shown on each representation of the apparatus by means of

* After the additional precautions for obtaining a better mixture of the gases, &c., had been introduced, several experiments of this class were made. But as it was found that the fire-damp flame was, if anything, shorter than before, sometimes not exceeding eight or nine feet in length, I did not think it necessary to undertake a new series of experiments, and allowed the original one to remain intact.

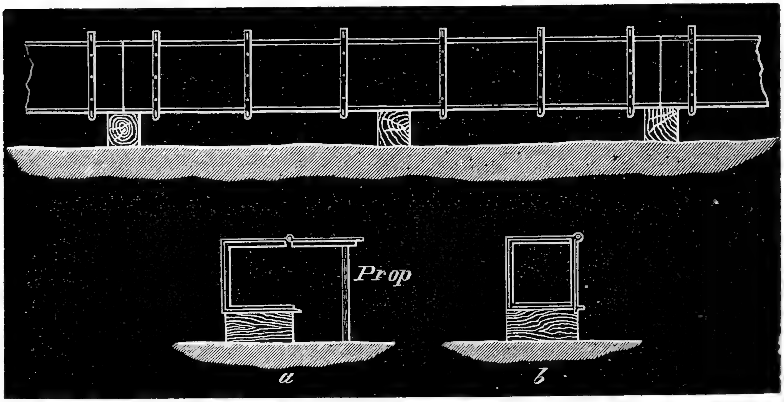
FIG. 2.



black lines drawn across the white ground. As the coal-dust flames issued from the apparatus they assumed various forms according to the direction in which the wind happened to drift the cloud of coal-dust and air which preceded them. Nos. 39 and 58 were bent backwards, as the wind was blowing against the open end of the gallery at the time; Nos. 43 and 59, on the contrary, were drawn out in the same line as the gallery, the wind favouring that development; the others are more or less doubtful.

Fig. 3 is a side view and two sections of the gallery on a larger scale than the last. The bands of iron which hold the wood-work

FIG. 3.



together and the supports on which the sections rest are also shown. In section (*a*) the door is open, in (*b*) it is shut.

All important details concerning each experiment will be found in the following table:—

Details of Sixty-three Experiments made at Lluyuypia Colliery, between the 14th and 21st of July, 1881.

Date.	Number of experiment.	Total quantity of fire-damp employed.	Sheets of paper in the diaphragm.	Length of the gallery strewed with coal-dust.				Position and weight of heaps of gunpowder.			Distance travelled by the flame.			
July, 1881.				Sections with doors shut.		Sections with doors open.		Weight in each heap.	Distance from diaphragm.	Whether burnt or not.	In the closed part of the gallery.	In the open part of the gallery.	Beyond the end of the gallery.	Total distance.
		Cb. ft.	No.	No.	Ft.	No.	Ft.	Oz.	Ft.		Ft.	Ft.	Ft.	Ft.
14	1	1·811	4	...	...	...	...	...	...	...	...	10½	...	10½*
,,	2	1·811	6	...	...	...	...	...	...	...	...	9	...	9
,,	3	1·811	6	...	...	...	...	...	...	...	...	10	...	10
,,	4	1·811	6	...	...	...	...	...	...	...	16	...	...	16†
,,	5	1·811	6	...	...	...	...	...	...	...	14	...	...	14
,,	6	1·811	6	...	...	...	...	...	...	...	12½	...	...	12½
,,	7	1·811	6	...	...	...	...	...	...	...	12	...	...	12
,,	8	1·811	6	...	...	...	...	...	...	...	15	...	...	15
,,	9	1·811	6	...	...	...	...	...	...	...	15	...	...	15
,,	10	1·811	6	...	...	...	...	...	...	...	15½	...	...	15½
,,	11	1·811	6	...	...	...	...	...	...	...	11	...	...	11
,,	12	1·811	6	...	...	...	...	...	...	...	12	...	...	12
,,	13	1·811	4	...	...	...	...	...	...	...	11½	...	...	11½
15	14	1·811	6	...	...	...	...	...	...	...	?	...	...	?
,,	15	1·811	6	...	...	...	...	...	...	...	13	...	...	13
,,	16	1·811	?	3	54	2	36	...	...	...	?	...	...	?
,,	17	1·811	?	3	54	2	36	...	...	...	?	...	...	?
,,	18	1·811	?	1	18	1	18	...	...	...	18	18	...	36‡
,,	19	1·811	?	2	36	2	36	...	...	...	36	26	...	62
,,	20	1·811	6	3	54	2	36	...	...	...	?	...	...	?
,,	21	1·811	6	3	54	2	36	...	...	...	54	5	...	59
,,	22	1·811	2	3	54	2	36	...	...	...	54	...	...	54
,,	23	1·876	6	3	54	2	36	...	...	...	54	24	...	78
,,	24	1·876	6	3	54	2	36	...	...	...	54	36	...	90
,,	25	1·876	6	3	54	2	36	...	...	...	54	30	...	84
,,	26	1·876	6	3	54	2	36	...	...	...	?	...	...	?
,,	27	1·876	6	3	54	2	36	...	...	...	54	4	...	58
,,	28	1·876	6	3	54	2	36	...	...	...	54	27	...	81
,,	29	1·876	6	3	54	2	36	...	...	...	54	38	...	92
,,	30	1·876	6	3	54	2	36	...	...	...	54	32	...	86
18	31	1·876	6	3	54	2	36	...	...	...	54	44	...	98§
,,	32	1·876	6	4	72	2	36	...	...	...	72	36	...	108
,,	33	1·876	6	4	72	2	36	...	...	...	72	32	...	104
,,	34	1·876	6	4	72	2	36	...	...	...	72	32	...	104
,,	35	1·876	6	5	90	2	36	...	...	...	?	...	...	?
,,	36	1·876	?	5	90	2	36	...	...	...	90	27	...	117‖
,,	37	1·876	6	5	90	2	36	...	...	...	90	36	2	128
19	38	1·876	6	5	90	2	36	...	...	...	90	10	...	100¶
,,	39	1·876	6	5	90	2	36	...	...	...	90	36	4	130
,,	40	1·876	6	6	108	1	18	...	...	...	108	9	...	117

* No coal-dust, and gallery wetted in the first fifteen experiments.

† Fan going and upwards of 1,000 cubic feet of air passing into the apparatus just behind the diaphragm until the forty-third experiment.

‡ It was now recognised that the open seams in the gallery ought to be closed, and this operation was effected gradually with strips of wood and canvas, &c., until the thirty-first experiment, when it was completed except along the bottom and at the joints of the doors, where the seams were left open.

§ Strips of canvas were nailed along two of the three seams in the bottom and along the joints of the doors of the first two sections. Also pieces of felt were introduced between the ends of the first four doors this day.

‖ Fresh dust was put into the first three sections only.

¶ Before experiments were begun this day strips of canvas were nailed along all the seams in the bottom and at the joints of the doors as far as the end of the sixth section.

Date.	Number of experiment.	Total quantity of fire-damp employed.	Sheets of paper in the diaphragm.	Length of the gallery strewed with coal-dust.				Position and weight of heaps of gunpowder.			Distance travelled by the flame.			
July, 1881.				Sections with doors shut.		Sections with doors open.		Weight in each heap.	Distance from diaphragm.	Whether burnt or not.	In the closed part of the gallery.	In the open part of the gallery.	Beyond the end of the gallery.	Total distance.
		Cb. ft.	No.	No.	Ft.	No.	Ft.	Oz.	Ft.		Ft.	Ft.	Ft.	Ft.
19	41	1·876	6	6	108	1	18	...	...	...	?	...	...	? *
,,	42	1·876	8	6	108	1	18	...	...	...	?	...	...	?
,,	43	1·876	6	6	108	1	18	...	...	...	108	18	15	141
,,	44	1·876	6	6	108	1	18	...	...	...	?	...	...	? †
,,	45	1·876	6	6	108	1	18	...	...	...	108	18	...	126
,,	46	1·876	6	6	108	1	18	...	...	...	?	...	...	?
20	47	1·876	6	6	108	1	18	...	...	...	?	...	...	?
,,	48	1·876	6	6	108	1	18	...	...	...	?	...	...	?
,,	49	1·876	6	4	72	3	54	...	...	...	72	50	...	122
,,	50	1·876	6	5	90	2	36	...	...	...	90	36	...	126
,,	51	1·876	6	6	108	1	36	...	...	...	108	18	21	147
,,	52	1·876	6	7	126	...	...	...	...	...	108	...	...	108
,,	53	1·876	6	7	126	...	...	...	...	...	?	...	...	?
,,	54	1·876	6	5	90	2	36	2 2	21 22	burnt ,,	90	36	4	130‡
21	55	1·876	6	7	126	...	...	$3\frac{1}{2}$ 3 2	18 36 72	not burnt burnt not burnt	126	...	27	153
,,	56	1·876	?	7	126	...	...	$3\frac{1}{2}$ 2 2	18 36 72	not burnt not burnt not burnt	?	...	...	? §
,,	57	1·876	?	7	126	...	...	4	21	burnt	126	...	22	148
,,	58	1·876	?	7	126	...	...	4 4	21 42	burnt burnt	126	...	8	134
,,	59	1·876	6	7	126	...	...	4 4 4	21 42 65	burnt burnt burnt	126	...	34	160
,,	60	1·876	6	7	126	...	...	4 4 4 4	21 42 65 87	burnt burnt burnt burnt	?	...	...	? ‖
,,	61	1·876	6	7	126	...	...	4 4 4 4	21 42 65 87	burnt burnt burnt burnt	?	...	...	?
,,	62	1·876	6	4	72	3	54	...	...	...	?	...	...	? ¶
,,	63	1·876	6	3	54	4	72	...	...	...	54	46	...	100**

* It was raining when the forty-first and forty-second experiments were made.

† Rain had ceased when the forty-fourth experiment was made.

‡ This result was obtained without putting in any fresh dust after the previous experiment was made.

§ The gallery had not been swept out, and no fresh dust was added after the last experiment. The soot was taken off the first and third heaps of powder, that had been left unburnt, and another heap was substituted for the one that had been burnt in the middle.

‖ In this case and the next the explosion of the powder seemed to arrest the progress of the flame, instead of accelerating it.

¶ There was fresh dust in the two first sections only.

** This flame came out of the last two sections and swept the ground, coking the dust lying at the three points it touched over an area of four or five square feet at each.

It should again be mentioned that a thick cloud of coal-dust and air was always created by the air-wave which emanated from the fire-damp explosion and swept through both the closed and open parts of the gallery, *in advance of* the flame. When this cloud emerged into the open air, either by drifting sideways from the open sections, or by being projected beyond the end of the gallery, it occasionally assumed large proportions, and the flame, which *afterwards* shot into it, also became enlarged until it appeared to have a diameter varying from 5 to 9 feet on different occasions. It then emitted a loud roaring sound and exhibited all the phenomena of incipient explosive combustion.

Crusts of coked coal-dust were found adhering to the edges of the transverse shelves farthest from the explosion chamber, and their opposite edges were covered with a thin deposit of soot and dust, which had a velvety feeling when touched. These circumstances seem entirely to corroborate the hypothesis first proposed in No. I paper, in connection with Llan Colliery explosion, and afterwards revived in No. III paper, in connexion with Penygraig Colliery explosion, to the effect that the crusts of coked coal-dust are, as a rule, deposited during the retrograde movement of the air, that is to say, *while it is travelling backwards towards the origin of the explosion.*

The results stated in the foregoing pages strengthen and confirm the opinions I have expressed in each of the three preceding papers on the same question, as to the manner in which the flame of an explosion is originated and propagated in a dry and dusty mine. The experiments described in the first paper seemed to show that a mixture of air and coal-dust is not inflammable at ordinary pressure and temperature without the presence of a small proportion of fire-damp; but those described in this place show conclusively, I think, that fire-damp is altogether unnecessary, when the scale on which the experiments are made is large enough, and when the fineness and dryness of the dust are unquestionable. It may be objected that, although the particular kind of dust I have generally employed may form an explosive mixture with pure air, it does not follow that other kinds of coal-dust will do the same, even under the very same conditions as to fineness and dryness. I am inclined to think, however, that the objection has very little real importance as far as the general question of colliery explosions is concerned. Possibly the dust produced in mines in which very *dry* or anthracitic qualities of coal are worked might not behave in the manner indicated. But the number of mines of this class now being worked in this country is far too small, as compared with the whole, to be of any practical account.

I may add, in concluding, that the views advocated in these papers, or similar ones, have been held for many years by a few eminent French engineers, including MM. Verpilleux, Vital, and others; and they now appear to be making rapid progress amongst the practical mining men of our own country, who, judging by the reports that have reached me from many sides, are urgently desirous of obtaining as much information on the subject as they possibly can.

March 30, 1882.

THE PRESIDENT (followed by THE TREASURER) in the Chair.

The Right Hon. Anthony John Mundella was admitted into the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. "On the Development of the Ossicula Auditus in the Higher Mammalia." By ALEXANDER FRASER, M.B., &c., Senior Demonstrator of Anatomy, the Owens College, Manchester. Communicated by Dr. ALLEN THOMSON, F.R.S. Received March 16, 1882.

(Abstract.)

The paper begins by a history of the various views held up to the present date concerning the origin of the Ossicula Auditus.

The author then describes the methods of preparation, and the results of his own observations made upon complete series of sections from the rat, pig, sheep, dog, rabbit, calf, mouse, and human embryos at different developmental stages. He gives a short anatomical sketch of the parts in connexion with the proximal extremities of the first two post-oral cartilages, including the ganglion, the maxillary and mandibular branches of the fifth nerve, the seventh nerve, and its mandibular (chorda tympani) branch (noting the relation which this branch bears to the hyoidean cartilage, and the long crus of the incus), the auditory vesicle and its capsule with the difference in development between the oval and round fenestræ, the primitive jugular vein, the hyo-mandibular cleft (and its non-perforation in the region of the membrana tympani), and the tympanic annulus.

The author describes the malleus as having its origin in the proximal extremity of the mandibular cartilage, the apex of which, growing in a ventral direction, depresses the dorsal wall of the meatus auditorius externus upon the ventral, and thus becomes the manubrium of the malleus. He further compares the embryonic ossicula with their form in the adult, and traces the origin from the mandibular cartilage of certain parts in the adult malleus of Mammalia of great morphological significance.

He has ascertained that the head of the incus is the proximal extremity of the hyoidean cartilage, the long crus forming the connecting part between it and the remainder of the cartilage. The short crus is a later growth backwards from the head of the incus. This ossicle agrees in its histological characters with the hyoidean cartilage and not with the mandibular. The mandibular branch of the seventh nerve bears also the same relation to its long crus in the human embryos as it bears to the hyoidean cartilage.

The orbicular apophysis is shown to be a part of the long crus, which turns inwards to accommodate itself to the stapes at right angles to its former direction; its constricted pedicle is not formed until after birth.

The cells of the embryonic stapes appear contemporaneously with those forming the embryonic cartilage in the arches, or those forming the periotic capsule; they are arranged in a circular form round an artery, which may either disappear very early, as in the human embryo, or persist through life, as in the rat. In the former case it is called arteria stapedialis, in the latter arteria stapedio-maxillaris. This circular ring is at first of equal thickness all round, and is not even in contact with the periotic capsule, but is more closely connected with the hyoidean cartilage, although its cells cannot be described as continuous with the cells of that cartilage, their long axes having a circular and not an antero-posterior direction.

Owing chiefly to the growth of the cochlear part of the labyrinth, the stapes applies itself to the wall of that cavity, forms a depression there, the future fenestra ovalis; the margins of its base and the head are the last to develop.

The articulation between the head of the stapes and the long crus of the incus is formed at the same time as that between the malleus and incus. The tubercle on its posterior crus bears the same relation to the stapedius muscle as the processus muscularis of Hyrtl to the tensor tympani. The stapedius muscle agrees in its development with the tensor tympani, or any other muscle in the region of the head, and the nucleus in its tendon, which has been described as an inter-hyal, has no connexion with the hyoidean cartilage, in truth, not being present at all in any of the embryos on which I have worked; so that when it is present it must be looked upon as a development in a tendon similar to that which occurs in many other muscles of the body.

The author was anticipated by Salensky in the publication of the discovery of the peculiar mode of origin of the stapes round an artery; but his observation of this fact was made independently of Salensky's, and before the appearance of that writer's memoir, and he has been able both to correct and to add considerably to Salensky's description of the development of this ossicle.

II. "Description of the Fossil Tusk of an extinct Proboscidian Mammal (*Notelephas australis*, Ow.), from Queensland, Australia." By Professor OWEN, C.B., F.R.S., &c. Received March 21, 1882.

(Abstract.)

The author, after referring to the notice of the finding of a molar tooth of a mastodon, in Australia, by Count Strzelecki, in his "Physical Description of New South Wales," p. 312, proceeds to the details of the first evidence of a proboscidian mammal which has reached him from that continent since the date (1845) of the Count's work. This evidence consists of portions of a tusk indicative of an elephantine animal, somewhat less than the existing ones of Asia and Africa. The evidences of the ivory nature of the tusk are given in detail, including the minute characters of that variety of dentine. Figures of the fossil and of the microscopical sections accompany the paper.

The specimen was discovered by Mr. Fred. N. Isaac, in a "drift-deposit of a ravine in a district of Darling Downs, sixty miles to the eastward of Moreton Bay, Queensland, Australia."

III. "Action of Ethylene Chlorhydrin upon the Bases of the Pyridine Series and on Quinoline." By Professor ADOLPH WURTZ, For. Mem. R.S. Received March 17, 1882.

According to the constitution which is generally attributed to the bases of the pyridine series, they must be considered as tertiary bases, their nitrogen being united to the carbon by three atomicities. The action which alcoholic iodides exert upon these bases, as shown by Hofmann, confirms this idea, which is equally applicable to quinoline. I thought that the reaction of glycol chlorhydrin and similar compounds upon the pyridine bases and upon quinoline should produce oxygenated quaternary bases. It is known, in fact, that such a base, neurine, results from the action of ethylene chlorhydrin upon trimethylamine. The beautiful results which Ladenburg obtained recently by the reaction of chlorhydrin upon secondary bases are well known. He is still continuing these researches to the great profit of science. I myself, entering again on a line of researches which I had formally traced, will describe the results obtained by investigations undertaken in the direction indicated, with the pyridine bases and quinoline.

I had two specimens of collidine at my disposal, presenting the same boiling-point. One obtained by the distillation of aldol-ammonia was undoubtedly identical with aldehydine of Baeyer and Ador (boiling-point 179—182° C.), the other was isolated from the pyridine bases formed by the distillation of cinchonine with hydrate of potassium; this collidine is the α-collidine (boiling-point 179—183°).* The experiments have proved that these two collidines are isomeric.

Action of Ethylene Chlorhydrin upon Aldehydine.

A mixture of these two compounds, in proportion of their molecular weights, to which a quantity of water weighing as much as the aldehydine employed was added, was heated during several days in closed tubes to 100° C. The oily layer which floated on the mixture at the end of the operation, continually decreased and finally disappeared after cooling. The aqueous liquid, which was slightly brown, was extracted with ether, and finally evaporated in the vacuum. The ether had dissolved a small quantity of unattacked aldehydine and chlorhydrin. The chlorohydrate, concentrated by evaporation, was mixed with an excess of platinum chloride, and alcohol was added to the mixture. An abundant crystalline precipitate was obtained, and was purified by several crystallisations in hot water. In this manner magnificent voluminous orange-red crystals of chloroplatinate of oxethyle-aldehydine were obtained. Their analyses furnished the following numbers :—

	Experiment.			Theory.
	I.	II.	III.	
Carbon	32·65	32·80	31·90	32·33
Hydrogen	4·46	4·45	4·53	4·31
Nitrogen	4·10	4·22	,,	3·77
Chlorine	28·24	,,	,,	28·70
Platinum	26·30	,,	25·84	26·27

The Analysis III, which is the most accurate, was executed with a salt which had been dried in the vacuum; when this salt is heated to 100° C. it loses hydrochloric acid, which tends to augment the proportion of carbon and of platinum. The Specimen III, after having been heated to 100° during some time, contains 28·2 per cent. of platinum. This alteration, which is more marked in the case of the chloroplatinate of oxethyl-collidine, will be examined later on. The results of these analyses lead to the formula $(C_{10}H_{16}NOCl)_2PtCl_4$, which is that of a chloroplatinate of oxethyl-aldehydine—

$$\left[C_8H_{11}\overset{v}{N}<^{OC_2H_5}_{Cl}\right]_2PtCl_4.$$

* The β-collidine which Mr. Oechsner de Coninck found amongst the cinchonine bases boils at 198°.

This chloroplatinate forms magnificent orange-red crystals of clinorhombic aspect. It is quite soluble in hot water, and the concentrated boiling solution, when it cools, becomes cloudy, by depositing oily drops which finally transform themselves into crystals. Decomposed in aqueous solutions by sulphuretted hydrogen, it furnishes a chloride whose solution is colourless, and does not crystallise after being evaporated during several days in the vacuum. Decomposed by oxide of silver and water it furnishes a caustic soluble base, which attracts the carbonic acid of the air.

These reactions permit no doubt as the character of the new base, which is a sort of aldehydine neurine.

Action of the Ethylene Chlorhydrin upon α-Collidine.

In order to obtain the α-collidine quaternary base corresponding to neurine the method just indicated was employed. The reaction is, however, more rapid than in the previous case; and after heating for a few hours the oily layer disappears, excepting a few black drops which still float on the liquid. The liquid on being extracted with ether, evaporated in the vacuum, and finally treated by platinum chloride, furnishes a crystalline orange-yellow precipitate less soluble in water, and much less stable than the preceding one. The analyses of this salt, dried over sulphuric acid, gave the following results :—

	Experiment. I.	Experiment. II.	Theory.
Carbon	31·23	..	32·23
Hydrogen	4·16	..	4·32
Platinum	26·32	26·16	26·48

The solution of this salt in hot water becomes of a deeper brown-red colour the more concentrated it becomes. On boiling it decomposes. Its solution in a large quantity of hot water, on cooling deposits orange-red crystals tinged with brown. These crystals give the following numbers when analysed :—

	Experiment. I.	Experiment. II.	Experiment. III. Orange crystals from the mother-liquor.	Theory.
Carbon	30·39	..	31·56	32·23
Hydrogen	4·09	..	4·18	4·31
Platinum	27·48	27·02	26·33	26·48

These crystals do not possess exactly the composition of the chloroplatinate, $(C_{10}H_{16}NOCl)_2PtCl_4$, which must therefore be altered by the action of boiling water. In fact, the solution became deeply coloured after several minutes' boiling,* and on being decomposed by sulphuretted hydrogen, furnished a solution which, after being evaporated on the water-bath and filtered, showed a brown tint, and gave after several days brownish-red crystals. These were purified by crystallisation from boiling alcohol, in which they are very slightly soluble. By the cooling of the solution a salt was obtained, which crystallises in brilliant scales, possessing a brownish tint, and corresponding exactly to the formula of a chloroplatinite of oxethyl-α-collidine, $C_{10}H_{15}(PtCl)NOCl$.

			Theory.
Carbon............	35·61	......	35·84
Hydrogen..........	4·79	......	4·42
Chlorine...........	20·89	......	21·30
Platinum..........	29·30	......	29·42

This salt is derived from the chloroplatinate of oxethyl-α-collidine by loss of hydrochloric acid:—

$$(C_{10}H_{16}NOCl)_2PtCl_4 = 2HCl + (C_{10}H_{15}NOCl)_2PtCl_2.$$

The crude chloride of oxethyl-α-collidine, or the chloride separated from the unaltered chloroplatinate by sulphuretted hydrogen, treated with chloride of gold, furnishes an abundant precipitate, which condenses directly into dark yellow drops.† These drops soon transform themselves into crystals, which melt under hot water, but are soluble in a large quantity of boiling water. The solution, when cooled, deposits first yellow drops, then magnificent thin needles of golden-yellow colour. They are the chloroaurate of oxethyl-α-collidine, $C_{10}H_{16}NOCl.AuCl_3$.

			Theory.
Carbon............	23·79	......	23·79
Hydrogen.........	3·35	......	3·17
Nitrogen..........	..	......	,,
Gold..............	38·96	......	38·91

Action of Ethylene Chlorhydrin upon Quinoline.

The quinoline which was employed in this experiment was obtained by distilling cinchonine with hydrate of potassium, and possessed, after a great number of rectifications, the boiling-point 238—240° C. The quinoline was heated with an equivalent quantity‡ of glycol chlorhydrin, to which its weight of water had been added. After

* In one experiment an elimination of a small quantity of platinum which blackened the liquid was noticed.

† With the crude chloride a dark coloration, due to a reduction of the gold salt by some impurity, is observed.

‡ 16 grs. of quinoline for 10 grs. of chlorhydrin.

three days' heating, the oily layer had entirely disappeared. The mixture was cooled and extracted with ether, and the aqueous solution, slightly coloured brown, was concentrated. After a few days, the solution contained a great amount of brown crystals, which were strongly pressed between layers of paper, and finally dissolved in absolute alcohol. The solution was treated with animal charcoal, filtered boiling, and, after cooling, anhydrous ether was added, so as to float on the alcoholic layer. The next day the alcoholic solution was filled with magnificent colourless prisms, some of which traversed the entire vessel. This salt is a chloride of oxethyl quinoline,

$$C_{11}H_{12}NOCl = C_9H_7\overset{v}{N}<^{OC_2H_5}_{Cl},$$

formed by the addition of glycol chlorhydrin to quinoline.

						Theory.
Carbon	63·20	....	..	....	63·01
Hydrogen	5·96	....	..	....	5·72
Nitrogen	6·83	....	..	....	6·68
Chlorine	16·29	....	16·11	....	17·42

This chlorhydrate has a bitter taste, attracts the atmospheric moisture, and is very soluble in water and in alcohol, insoluble in ether. Its aqueous solution is not precipitated by ammonia, and gives with potassa a thick, coloured precipitate. Boiled for several seconds with oxide of silver, the solution forms chloride of silver and reduced silver, and the filtered liquid possesses a very strong alkaline reaction, and rapidly assumes a crimson tint. The hydrate of plumbic oxide decomposes this chloride in a similar manner. Corrosive sublimate forms with it a compound which crystallises easily.

Chloride of gold produces, in the solution of this chloride, a yellow precipitate, soluble in boiling water, from which it crystallises on cooling in small crystals, which appear under the microscope as pointed lozenges. This chloroaurate possesses the formula

$$C_{11}H_{12}NOCl,AuCl_3.$$

			Theory.
Carbon	26·21	......	25·77
Hydrogen..........	2·94	......	2·34
Gold	37·98	......	38·30

Platinum chloride forms a chamois-yellow precipitate in the solution of the chloride. This precipitate is soluble in a large quantity of boiling water, and crystallises from the cold solution in small opaque orange crystals of the formula $(C_{11}H_{12}NOCl)_2PtCl_4$.

	Experiment. I.	II.	III.	Theory.
Carbon	35·03	34·54	35 09	34·82
Hydrogen	3·41	3·35	3·35	3·16
Nitrogen	3·70	„	„	3·70
Chlorine	„	„	27·4	28·09
Platinum	26·09	26·8	26·9	26·0

The Specimen I was the pulverulent yellowish chloroplatinate, simply precipitated and dried in the vacuum. The others had been dissolved in boiling water, and were thereby slightly altered, as the excess of platinum proves. When quinoline is heated with an equivalent quantity of ethylene chlorhydrine without adding water, a dark purple-reddish mass is obtained. Extracted with ether, dried and treated with absolute alcohol, this mass gives a dark violet solution, which, if ether is poured on it, deposits an almost black mass, which finally crystallises. The crystals, pressed between sheets of paper, are sensibly less coloured than the mother-liquor, which imparts to the paper a dark violet colour.

I have not yet concluded the analysis of this product, and I propose to continue these researches in various directions.

IV. "On the Movement of Gas in 'Vacuum Discharges.'" By William Spottiswoode, P.R.S., and J. Fletcher Moulton, F.R.S. Received March 25, 1882.

In the preparation of tubes for our experiments it was often noticed that, after the exhaustion had been carried to a certain degree, the passage of a strong current had the effect of increasing the pressure. This appeared to be due to an expulsion of gas from the terminals themselves by the passage of the discharge. And accordingly the use of such currents from time to time during the process of exhaustion was adopted for making the vacuum more perfect and more permanent than otherwise would have been the case. On the other hand, it was also noticed, that after the tube had been taken off the pump and sealed in the usual way, the passage of a strong current had in some instances the effect of decreasing the pressure. We thus met with two effects, apparently due to the same cause, but diametrically opposite in character.

The fact of the tube being on the pump or off it did not appear to be at all material to the question, because the first effect could be obtained when the tube was temporarily shut off by a stopcock. Nor indeed did either the first or the second effect depend upon the absolute pressure, although neither was observed except when the pressure was such as to approach the stage when Crookes' phosphorescence was produced.

These phenomena also reproduced themselves in another way. Some tubes, after having been completed and taken off the pump, showed a decreased pressure after a prolonged passage of a strong current, others an increased pressure, but among both classes tubes were not unfrequently found which recovered their original pressure after a period of rest or cessation of discharge.

Matters remained in this rather confused state until we observed with more care than before a tube of which the exhaustion was near the phosphorescent state, and of which both terminals were metallic cones, and consequently presented large surfaces for any action which might take place upon them.

In what may be considered to have been its normal condition, this tube showed three or four large white striæ with a dark space of considerable size round the negative terminal. On passing the discharge through the tube for some minutes the dark space increased, the striæ became fewer and feebler in illumination, the green phosphorescence began to show itself, and the discharge showed the usual signs of reduced pressure. On suddenly reversing the current the striæ became again more numerous and more brightly illuminated, precisely as they would be by an increase of pressure, while the other features of the discharge in a great measure resumed their original character; and not only so, but by a comparatively slow process, occupying many seconds in duration, the indications of increasing pressure continued still further, until they implied a pressure even beyond that at which the tube stood when the experiments began, after which the appearance slowly changed as before in a manner indicating reduced pressure. This reversal of the discharge was repeated many times with the same result in every case. The amount of change in pressure indicated by the appearance on each reversal was found to depend within wide limits upon the duration of the previous discharge, or, what is the same thing, upon the amount of depression below the normal pressure indicated by the previous discharge.

The most probable explanation of these phenomena appears to be this, that the effect of the discharge is actually to alter the pressure in the tube, not by any modification in the chemical composition of the gas, still less by anything that could be represented as a destruction of matter, but simply by driving occluded gas out of one terminal, and by drawing it in, or occluding it, at the other. On reversing the discharge, the operation is reversed, and the occluded contents of one terminal are thrown along the tube to be occluded at the other. This view of the mechanism whereby the observed phenomena are produced is supported by the absence of these appearances when the terminals are comparatively small and the pressure is such that the occluded contents of the metallic mass forming one terminal would form only a small fraction of the total mass of gas in the tube; for in that case the pressure, and consequently the appearance of the discharge, would be affected only in an inappreciable degree by the injection of the contents of the terminal. It should also be added that, when the terminals are of unequal size, the effects are unequal, as might have been expected.

The phenomenon in question appears to have so important a bearing on the mechanism of the discharge itself, that it becomes a question of great interest to determine whether the missing gas is to be found in either of the terminals; and if so, whether the ejection takes place at the positive, and the occlusion at the negative, terminal, or *vice versâ.* For this purpose I have devised a tube with three terminals, but have not yet had time to complete its construction or to make the experiment.

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"The Effects of certain modifying Influences on the Latent Period of Muscle Contraction." By GERALD F. YEO, M.D., F.R.C.S., and THEODORE CASH, M.D. Communicated by Dr. SANDERSON, F.R.S. Received June 15. Read June 16, 1881.

Although the labour of many physiologists has been directed towards the consideration of Latency, it seemed to us desirable that the subject should receive a little addition in some of its details, and it was with the object of thus filling up deficiencies, and at the same time of studying systematically the effect of some of the agents which modify the time of latency, that we undertook the investigations, the results of which we desire to lay before the Society.

In 1867 Helmholtz and Baxt* published the results of experiments they had instituted touching the speed of conduction in motor nerves as measured by the relative latencies obtained in a nearer and more distant stimulation of a nerve-trunk (frog) or of the skin above it, and in publishing their experiments of 1870 they drew attention to the modifying influence of temperature upon such conduction. Thus

* "Monatsbericht d. Berliner Acad.," 1867, s. 228, and 1870, s. 184.

they saw the speed decreased to a great extent when the nerve was laid upon ice, and even slight variations in the room temperature sufficed to produce material changes. Troitzky* came to the conclusion that conduction is the most rapid in the frog's nerve between 10° and 20° C., and diminishes both by higher and lower temperatures. The influence of temperature could, however, he concluded, be subordinated to a certain extent by increasing the strength of the stimulation.

That a powerful shock is more potent to induce rapid conduction than a weaker one has been upheld by Valentin† and von Wittich as well as by Troitzky, but has been denied by Rosenthal‡ and Lautenbach.§ These interesting results would have been still more valuable had accurate corrections been made for the variations in the rapidity of the initial changes taking place in the muscle itself during the latent period, for, as Hermann suggests, changes in the strength of the stimulus may cause these variations to be considerable.

An instrument, designed by du Bois Reymond — the "Frosch-Unterbrecher"—has made the fact apparent that the period of latent energy elapsing between stimulation and obvious contraction also increases if increasing weights, acting as "after-weights," be laid in the supported pan suspended from the muscle. Thus, whilst at lever-tension—at which point the support was fixed—the latency may be less than $\frac{1}{100}$ second, under a weight of 200 grms. it may be more than twice as much. It is evident that whether the muscle be "free-weighted" or "after-weighted," until it has reached a state of counterbalancing tension as regards the weight it is to raise, no elevation from the abscissa can be effected. The free-weighted muscle is already stretched as regards the greater number of its fibres by a small weight (30—40 grms. for gastrocnemius of frog), whilst the after-weighted has to attain a similar state of tension before it can commence its true lift. Variations in latency are then to be expected according to the connexion in which we place the weight and the muscle. Place|| and Klunder¶ remark that if, after a muscle has been powerfully extended, and while it is returning, by reason of its elasticity, towards its normal condition, a stimulation be applied, the latency may become as short as the $\frac{1}{200}$—$\frac{1}{400}$ second, a result which Haidenhain** inclines to attribute to the pernicious effects of the previous tension.

* "Arch. für d. ges. Physiologie," viii, s. 599, 1874.

† Moleschott, "Untersuchungen," x, s. 526, 1866.

‡ "Monatsbericht d. Berliner Acad.," s. 419, 1875.

§ "Archiv. d. Science Phys. et Nat.," Juli, 1877.

|| "Handbuch der Physiologie," Bd. 2, p. 24.

¶ "Nederlandsch Arch. v. Genees en Naturk.," iii, p. 177, 1867.

** "Untersuchungen aus dem Kieler Institut," p. 101, 1868.

The instrument which served us for registration of the contraction was a modification of Fick's pendulum myograph, manufactured by the Cambridge Scientific Instrument Company. It was provided with an extensive arc, having movable catch adjustments, so that the velocity of the recording surface could be readily modified. The primary current was broken by the arm of the swinging pendulum, and if occasion required a second contact, the relation of which to its neighbour could be regulated by a micrometer screw, could be employed in conjunction. The recording plate could be elevated so as to register a series of some 30—40 curves, one over the other. The moist chamber, containing the muscle, &c., was placed on a table which could be withdrawn or advanced to meet the plate (acting like the slide-rest of a lathe) without altering the relationship of the writing point to the recording surface. Within the moist chamber, and surrounding the muscle, passed several coils of metal tubing, which could be heated or cooled at pleasure by passing heated or iced water through it from a system of tubes terminating above in double funnels.

The temperature was accurately measured by a Centigrade thermometer placed in the moist chamber, its bulb being equidistant from the muscle and the tubing. The lever, designed by one of us, was made of two straws separated to the extent of $1\frac{1}{2}$ inch at their union with the axis, and converging at the other end to a pointed strip of platinum foil, which acted as a pen. The weight of this lever, without the friction of the pen, was about 1 grm. The weight was suspended round the axis of rotation, except in those cases in which it appeared desirable to apply it in the line of traction of the muscle. Great steadiness, absence of appreciable friction, and elimination of the effect of the "throw up" sustained by a lever weighted anywhere except at its axis, were ensured by this adjustment, and the great lightness of the lever arm.

In view of the fact that the nerve is more rapidly influenced by those agents which we proposed to employ in modifying the manifestations of latency, and also because we desired to look chiefly to the actual effect such agents produced on the changes necessary to the subsequent contraction, rather than to the varying conductivities of the nerve, we chose the curarised muscles (the gastrocnemius of the frog) for the bulk of our experiments. We may mention in this place that we found the variations between the non-curarised and curarised muscles, both stimulated directly and at room temperature (17—18° C.), so slight that they may be disregarded.

Maximal stimulation was employed in all cases, except where otherwise specified. Our experiments were performed on *Rana temp.*, between the 10th January and the middle of April.

Though we have thought well to give frequently the measurement of a series of curves taken from a single muscle, we have done this only in order to show a sample selected from a large number of curves, and presenting in a fair degree the peculiarities which custom has taught us to expect from the circumstances of the case.

The first experiments were directed to contrasting the latencies of contractions obtained by stimulating nerve or muscle.

The length of nerve attached to the preparation which yielded the following measurements was 12·5 millims. The weighting of the muscle was free, and the weights which were suspended sufficiently long before stimulation to cause a proportionate extension increased from lever weight, *i.e.*, 1 grm., up to 100 grms.

The duration of the latency and of the contraction is expressed in figures indicating the number of double vibrations of the tuning fork used to record the time. Each D.V. corresponds to $\frac{1}{180}$ of a second, which fraction of time therefore forms the unit in the following tables. The altitude of the curve is given in millimetres.

Table I.—Stimulation of Gastrocnemius Indirect and Direct.

	No.	Weight.	Length of latency in $\frac{1}{180}''$.	Length of curve in $\frac{1}{180}''$.	Altitude in mm.
Muscle ...	22	Lever	2	24·8	25·0
Nerve.....	21		2·75	23·75	24·5
M........	20	10 grms.	2·25	22·6	22·3
N........	19		3·05	21·5	22·0
M........	18	20 "	2·35	22·0	21·0
N........	17		3·10	21·3	21·3
M........	16	30 "	2·4	21·75	19·5
N........	15		3·25	21·0	20·0
M........	14	40 "	2·55	21·5	18·0
N........	13		3·4	21·5	18·0
M........	12	50 "	2·6	21·5	16·5
N........	11		3·45	20·5	17·0
M........	10	60 "	2·65	21·5	15·2
N........	9		3·5	20·7	15·2
M........	8	70 "	2·75	21·75	14·4
N........	7		3·55	20·5	14·4
M........	6	80 "	3·05	22·0	14·2
N........	5		3·65	21·35	14·2
M........	4	90 "	3·12	22·0	14·5
N........	3		3·75	21·9	14·0
M........	2	100 "	3·2	22·75	13·5
N........	1		4·0	22·0	13·5

The fact that the increase of weights causes an increase of latency will be at once appreciated after an examination of the table. The latency of contraction under lever weight when the stimulation is direct is ·0111″, and when indirect ·0152″. Under 50 grms., direct ·0144″, indirect ·0191″; and under 100 grms., direct ·0177″, indirect ·0222″.

Striking a mean between the light and heavy weight we should obtain the figures—for the direct ·0144″, and for the indirect ·0187″, both of which approximate closely to the experimental measurements of the middle weight.

If we tabulate, for increasing weights, the actual increase of the latencies, so that the prolongation for each increment may be readily recognised, we find in $\frac{1}{180}''$:—

Weight increase.	Latency increase. Muscle.	Nerve.
10 grms.	·25	·30
20 „	·10	·05
30 „	·05	·15
40 „	·15	·15
50 „	·05	·05
60 „	·05	·05
70 „	·10	·05
80 „	·30	·10
90 „	·07	·10
100 „	·08	·25
	1·20	1·25

The greatest difference appears to obtain at the extremes of the scale, *i.e.*, when the weight is first applied, and when it is beginning to be too severe for the muscle, whilst in the middle part of the series the variations are slighter and more uniform in character. If we glance at the other two columns in Table I, we see that this middle part contains the shortest curves exhibiting altitudes midway between those of the extremes. The fact established by Marey,* that a muscle hindered by the weight applied to it from reaching its maximum of contraction is slower in its relaxation than its less weighted neighbour, accounts for the long low curve under 100 grms.

As regards the comparison between the muscle stimulated directly and indirectly, we may state from our results, that which previous consideration had convinced us must be the case, viz. :—

At ordinary room temperature, the increase of latency bears the same proportion to the increase of free burden in direct as in indirect stimulation.

2. It has been alledged that curare increases the latency, and as we desired to use the curarised muscle in certain of our experiments, we made comparative observations with the result of convincing ourselves that as a rule no such prolongation occurs; but that the course of latency of the curarised and of the non-curarised muscle, *both* stimu-

* "Du Mouvement dans les Fonctions de la Vie," 1868, p. 363.

lated directly, and under varying burdens but constant room temperature, is strictly parallel. Upon the influence which curare may exercise upon the curve of contraction, we cannot enter here. The weight was gradually increased from lever to 100 grms.

Table II.—Contrast between Curarised and Non-Curarised Muscle.

No.	Weight.	Length of latency in $\frac{1}{180}''$.		Length of curve in $\frac{1}{180}''$.		Altitude in millims.	
		Non-cur.	Cur.	Non-cur.	Cur.	Non-cur.	Cur.
1 and 1a	Lever	1·85	1·85	30·0	29·5	31·5	29·0
2 „ 2a	10 grms.	1·9	1·9	24·5	26·0	20·0	17·5
3 „ 3a	20 „	2·02	2·0	23·0	20·5	17·5	15·0
4 „ 4a	30 „	2·10	2·05	22·5	20·0	16·5	13·5
5 „ 5a	40 „	2·30	2·25	21·75	19·75	16·0	11·5
6 „ 6a	50 „	2·47	2·5	21·25	19·6	15·0	11·0
7 „ 7a	60 „	2·5	2·6	21·20	19·75	13·5	11·0
8 „ 8a	70 „	2·65	2·72	21·25	20·0	13·0	10·5
9 „ 9a	80 „	2·80	2·85	22·35	20·5	13·5	10·0
10 „ 10a	90 „	2·90	2·95	22·5	21·5	12·25	9·5
11 „ 11a	100 „	3·00	3·00	22·75	22·0	12·0	9·0

There are slight variations usually in the second place of decimals between the two columns, but if the figures are—as we believe them to be—true measurements, we still require more extensive proof of a permanent difference than the occasional variation of a $\frac{1}{3000}''$.

Our result then is that at room temperature, the latency of the curarised and non-curarised muscles directly stimulated is equal for equal weights.

3. What is the relationship as to latency of the free-weighted muscle tensed in proportion to the weight it carries, to the after-weighted muscle, which has only the same slight initial tension under similar weights? As this question seemed to us to be an interesting one, we made a few observations, so as to obtain a fair contrast between two muscles placed under these widely differing circumstances.

The after-weighted muscle was supported, so that the weight of 10 grms. just rested upon the catch, from which the contracting muscle raised it. We give a double column of the resulting differences of the free-weighted and the after-weighted muscles.

The influence of the support seems to increase the earlier latencies, and it is in great measure owing to this effect that the variation is so much greater in the case of the after-weighted than of the free-weighted muscle.

Table III.—Contrast between Free-weighted and After-weighted Muscle.

Weight increment.	Decrease in Latency. Free-weighted.	After-weighted.
Lever to 10 grms.	0·25 of D.V. = $\frac{1}{180}''$	0·45 of D.V. = $\frac{1}{180}''$
10 grms. „ 20 „	0·05 „	0·20 „
20 „ „ 30 „	0·05 „	0·05 „
30 „ „ 40 „	0·10 „	0·0 „
40 „ „ 50 „	0·13 „	0·05 „
50 „ „ 60 „	0·06 „	0·05 „
60 „ „ 70 „	0·06 „	0·05 „
70 „ „ 80 „	0·05 „	0·20 „
80 „ „ 90 „	0·15 „	0·05 „
90 „ „ 100 „	0·10 „	0·10 „
	1·00	1·20

The weight of the lever alone (about 1 grm.) leaves many of the fibres of the gastrocnemius not tensed, and this condition is closely parallel to a mechanical support of a heavier weight. If the weight can be lifted without the co-operation of these fibres, the latency is short, but should the addition of only 10 grms. require the tension of many of them, the latency becomes markedly increased. Thus it is that the greatest differences lie towards the commencement of the scale of weight increment of a free-weighted muscle, and thus that the after-weighted muscle shows such greatly prolonged latencies at the same period.

We conclude therefore—

That the latency of a muscle with supported weight is greater than with unsupported weight, and that the greatest variation between the two occurs under the lighter weights.

4. We have referred at the commencement of this paper to the influence of weight upon latency, and we have shown subsequently that the addition of 100 grms. causes a marked prolongation of this period. As we desired as far as possible to avoid fatiguing the muscle, we did not carry our weights, as a rule, beyond 100 grms., though a few observations on fresh muscle weighted with 200 grms. were made in order to see in what manner the further weight acted. If we examine the prolongation of the latency caused by increasing the weight gradually from lever weight to 100 grms. we find that there is an average increase of about ·0063″.

In glancing over a number of observations and preparing their averages, we found that the greatest influence exercised by any one weight-difference (of a series of equal increments), was that resulting from the suspension of the first 10 grms. from the lever; this might cause an average increase of ·1625 D.V. The application of the three succeeding 10 grm. weights would have a conjoined effect of ·3384 D.V. The middle weights 40—70 grms., as has been already noticed, have less influence in prolonging the latency, their value would be about ·284 D.V., whilst the last series of these has again a much larger effect, equal together to ·354 D.V.; thus the extremes show greater variations amongst themselves than do the constituents of the intermediate series.

Lever to 10 grms.	·1625 D.V.	= ·0009″
10 grms. to 20 grms. 20 " " 30 " 30 " " 40 "	·3384 "	= ·00187″
40 " " 50 " 50 " " 60 " 60 " " 70 "	·284 "	= ·00157″
70 " " 80 " 80 " " 90 " 90 " " 100 "	·354 "	= ·00196″
Total	1·1389	

We feel inclined to hazard a corresponding division on mechanical grounds as follows :—

Lever (wt. 1 grm.)=tension of many muscle bundles very incomplete.

10—40=these bundles brought into action by the added weight.

40—70=all bundles active and unwearied.

70—100=strain of some of bundles, commencing weariness.

During the suspension of the second 100 grms. the variation in latency only amounts to about one-half of that which obtains during the first 100 grms.

Latency is then prolonged by increasing the weight, but it does not increase in a definite ratio to the increase of such weight.

5. Our attention was next turned to the effect of fatigue upon the muscle in modifying the latency occurring after stimulation. To induce fatigue we delivered to the muscle a certain number of opening induction shocks—maximal intensity—in a given time, or we admitted an interrupted current completely tetanizing the muscle for a specified period. After the muscle had remained at rest for a short interval a curve was taken, and the comparison of the latency of this curve with that taken before the tetanus or induction shocks had been administered was supposed to represent the effect of the stimulation which had intervened. A weight of 10 grms. only was applied to the lever during these experiments, so that injury from undue tension of the

muscle fibres might be avoided. The temperature of the room was from 17° to 18°·5 C.

In the case of fatiguing by simple induction shocks, 100 stimulations were delivered (one every 2″) from Ludwig's clock between the registration of every two stimulations. The results showed that whether in the case of the curarised muscle or of the healthy muscle stimulated indirectly, the first 5—700 shocks produced but very slight changes, not amounting frequently in all to an increase of over $\frac{1}{10}$ of a double vibration, or ·00055″.

A curious result occurring occasionally after a few hundred stimulations only had been administered was that the latency became actually diminished to a slight extent, namely ·00027″ to ·00044″, as if the moderate amount of exertion through which the muscle had passed favoured the more rapid consummation of the changes in the muscle preliminary to contraction. This diminution was followed by a return through the original to a more rapidly increasing latency. The prolongation after 900—1,000 contractions is distinct ·00132″ to ·00222″, whilst after 1,300—1,500 a rapid prolongation associated with loss of excitability (as shown by the long shallow curve with greatly retarded relaxation) is seen.

The following figures illustrate the course of such a case. *Gastrocnemius*, 100 contractions produced after each curve by maximal stimulations given every 2 seconds. About 1′ rest between each set of stimulations.

Latency in fraction of D.V.$=\frac{1}{180}$″.

Normal latency	=2·2
100 stimulations	=2·2
200 „	=2·15
300 „	=2·15
400 „	=2·18
500 „	=2·2
700 „	=2·2
1,000 „	=2·45
1,300 „	=3·15

When *tetanus* was used as a means of fatigue the interrupted current was admitted for 10″ to the muscle, and after the fibres had relaxed so that the lever had regained the original abscissa the comparison curve was taken.

We find that the change occurring in the latency is not altogether dissimilar to that of the muscle stimulated by simple induction shocks, that is to say, that the increase during the first 6—8, 10″ stimulations is not very great; but that after this point the latency tends to increase rapidly till at the 13th, 15th, 10-second tetanus a much prolonged latency with an associated low, long curve, showing great viscosity or slowness of extension, is to be observed. It differs in this respect, however, that the lengthening of the latency is already well marked after the muscle has been subjected once or twice to the 10″ tetanus. It is not unusual after a lengthening of the latency has occurred for it again to diminish, if not to a point below the original, at any rate to one distinctly below some of its predecessors. This peculiarity does not persist to the point at which the viscosity of the muscle becomes increased and the curve much prolonged, but coexists with a strong contraction followed by complete relaxation, and this point, be it coincidence or not, is worthy of note.

The following figures show the frequent course of such an experiment:—

	Length of Latency in D.V. = $\frac{1}{180}$″.
Fresh	3·0 ,,
After 10″ tetanus	3·12 ,,
,, 20 ,,	3·25 ,,
,, 30 ,,	3·3 ,,
,, 40 ,,	3·38 ,,
,, 50 ,,	3·12 ,,
,, 60 ,,	3·15 ,,
,, 70 ,,	3·50 ,,
,, 80 ,,	3·0 ?* ,,
,, 90 ,,	3·6 ,,
,, 100 ,,	4·8 ,,
,, 110 ,,	4·0 ,,
,, 120 ,,	4·2 ,,

120″ tetanus administered in the course of about 30′ at regular intervals causes a prolongation of ·00666″. Fatigue is more rapidly induced by indirect than by direct stimulation.

Fatigue then increases the latency, at first slowly (500 induction shocks or 60″ tetanus), and then more rapidly till the exhaustion of the muscle (1,500 single contractions or 130″ tetanus) when a much prolonged latency occurs. Near the commencement of stimulation a temporary diminution of the latency is occasionally to be recognised.

6. We have mentioned, at the commencement of this paper, that Helmholtz, Wundt, and others regarded the strength of the shock as playing an important *rôle* in modifying the length of latency, and we also pointed out that this view had been opposed by Rosenthal and Lautenbach. As the question appeared of importance, we directed our attention to it, in the hope that we might be able to contribute something to its elucidation.

* The muscle was apparently contracting slightly when stimulation was delivered.

Our method of procedure was to remove the secondary coil of du Bois Reymond's induction apparatus to a considerable distance from the primary and gradually to approximate it, testing both directions of the current in each instance till distinct contraction producing a legible curve was obtained. Electrodes were applied to both nerve and muscle, so that the position of the secondary coil at which direct or indirect stimulation caused contraction might be noted. A much more closely approximated position of the secondary coil to the primary is necessary for direct stimulation to be effective than for indirect. One Daniell was employed in the earlier experiments and in the later two Grove's elements were introduced into the primary circuit.

A contraction first occurred when the secondary coil (opening shock indirect) stood at 28 centims. No other mode of stimulation was effective till an approximation of 9 centims. was reached, when an indirect closing shock became operative. At 6 centims. direct opening shocks produced contraction, but the most powerful direct closing shocks, of which the apparatus and the single element were capable, were ineffective.

The contraction here, though maximal for indirect was submaximal for direct stimulation. The shock was at no point exhausting to the muscle for the altitude and length of the contraction, except in the case of the first, which is distinctly submaximal, remain remarkably constant throughout the experiment. The total result of the experiment may be expressed in four figures.

Gastrocnemius. Indirect stimulation: increasing strength.

1st stimulation:	coil at	28	centims.	....	Latency	=3·0	$\frac{1}{180}''$
10th	,,	19	,,	....	,,	2·95	,,
20th.	,,	10	,,	....	,,	2·90	,,
30th	,,	0	,,	....	,,	2·85	,,

or, in other words, the diminution of latency under this increase of stimulation was only ·15, or the ·0008″, an effect so slight that it may pass almost without notice in ordinary experiments, but is nevertheless of sufficient value in showing that an increase of intensity of stimulation, only carried so far as to produce a continuance of healthy reaction, still modifies the latency to a certain extent. The temperature of the room, 17°·5 C. remained constant during this observation.

In another experiment, two Grove's cells (small) were substituted for the Daniell, and thus a much greater potential was available for stimulating purposes. The muscle was uncurarised and the stimulation direct.

Table IV.—Influence of Stimulation. D.V. $= \frac{1}{180}''$.

No.	Weight.	Secondary coil.	Length of latency.	Length of curve.	Altitude.	Remarks.
1	10 grms.	20 cm.	3·75 d. v.	19·4 d. v.	7·0 mm.	
2	„	18 „	3·60 „	20·0 „	13·0 „	
3	„	16 „	3·5 „	19·3 „	24·0 „	
4	„	14 „	2·75 „	19·0 „	27·0 „	
5	„	12 „	2·55 „	18·5 „	26·5 „	
6	„	10 „	2·35 „	19·7 „	26·5 „	
7	„	8 „	2·10 „	19·8 „	27·0 „	
8	„	6 „	2·05 „	19·7 „	25·0 „	
9	„	4 „	2·05 „	26·0 „	26·5 „	
10	„	2 „	2·05 „	..	37·0 „	Does not regain abscissa, but shows indication of end of active phase. (Nos. 10–15)
11	„	0 „	2·15 „	..	33·0 „	
12	„	2 „	2·25 „	..	33·0 „	
13	„	4 „	2·25 „	..	27·0 „	
14	„	6 „	2·3 „	..	20·0 „	
15	„	8 „	2·45 „	27·7 „	16·0 „	
16	„	10 „	2·55 „	22·5 „	13·0 „	
17	„	12 „	3·00 „	21·1 „	12·0 „	
18	„	14 „	3·45 „	22·2 „	10·0 „	
19	„	16 „	3·65 „	23·2 „	9·5 „	
20	„	18 „	..	..	..	
21	„	20 „	3·8 „	23·0 „	8 „	No curve was taken at 12 cm.

We have here abundant proof, that without exerting a strength of stimulation sufficient to destroy contractility, we can reduce the latency through $\frac{1 \cdot 7}{180}$, or the ·0094″. From the time the secondary coil came within 4 centims. of the primary whilst it was pushed "home," and until it was removed again to 8 centims. from the primary, no curve produced reached the abscissa during the passage of the registering plate: there was an alarming viscosity manifested, and we feared injury to the muscle, but on distancing the induction coil a pretty fair recovery was made, the latencies rapidly lengthening, till at the position in which a value of 3·75 was first obtained, 3·8 was now recorded, the curve meanwhile, though somewhat (3·6 D.V.) lengthened, approximated to its primal form.

This experiment was repeated again with curarised muscles, and the result obtained coincided with our former experience in the abridgement which the latency undergoes under increase of stimulation. We give, in Table V, an illustration of increase of stimulation, ultimately proving fatal to the muscle.

Table V.—Curarised Gastrocnemius. Two small Grove's Elements.

No.	Weight.	Secondary coil.	Length of latency.	Length of curve.	Altitude.	Remarks.
1	10 grms.	13·5 cm.	3·45 d. v.	19·8 d. v.	12 mm.	
2	,,	13·0 ,,	3·25 ,,	19·8 ,,	14 ,,	
3	,,	12·5 ,,	2·75 ,,	20·2 ,,	16 ,,	
4	,,	12·0 ,,	2·4 ,,	20·6 ,,	21 ,,	
5	,,	11·0 ,,	2·3 ,,	20·8 ,,	25 ,,	
6	,,	10·0 ,,	2·25 ,,	20·0 ,,	27 ,,	
7	,,	9·0 ,,	2·25 ,,	19·7 ,,	25 ,,	
8	,,	8·0 ,,	2·2 ,,	19·7 ,,	25 ,,	
9	,,	7·0 ,,	2·2 ,,	20·0 ,,	27 ,,	
10	,,	6·0 ,,	2·10 ,,	20·5 ,,	29 ,,	
11	,,	5·0 ,,	2·25 ,,	does not terminate	30 ,,	The first contraction of this muscle occurred at 25 centims. of secondary coil, and had a latency of 4 d. v. As curve is indistinct up to 20 centims. Latency is omitted.
12	,,	4·0 ,,	2·25 ,,	2·6 d. v.	30 ,,	
13	,,	3·5 ,,	2·4 ,,	..	28 ,,	
14	,,	3·0 ,,	2·35 ,,	..	27 ,,	
15	,,	2·5 ,,	2·3 ,,	..	26 ,,	
16	,,	2·0 ,,	2·25 ,,	..	26 ,,	
17	,,	1·5 ,,	2·8 ,,	..	25 ,,	
18	,,	1·0 ,,	2·85 ,,	..	25 ,,	
19	,,	0·5 ,,	3·65 ,,	..	20 ,,	
20	,,	0 ,,	..	lasting contraction	16 ,,	Muscle dies at last stimulation.

Our first latency in this chart commences with the secondary coil, 13·5 centims. from the primary, and has a value of 3·45 D.V., and this we find at 6 and 7 centims. curtailed to 2·2, the smallest figure recorded. At this point (6 centims.) the curves which have hitherto been of fairly equal lengths, though of increasing altitude, show a considerable elevation after the active phase of contraction is over, the lever pen failing to reach the abscissa for some time after the plate has passed. The stimulation is still increased and the muscle remains longer contracted, whilst the curve falls in altitude; a stage of irritability which lasts till the secondary roll has passed 1·5 centims., and which is attended with short though varying latencies, passes, and after a sudden and extensive prolongation of the period, the last shock delivered with the coil "home" kills the muscle completely, the last latency being 3·65 D.V. We have here, then, a case in which the violence of the shock at last employed, kills the muscle and death is preluded by a distinct lengthening of latency, so that we cannot ascribe the changes of the earlier part of this series to morbid processes, any more than the shortening of those of the table last considered, though the strength of the shock when the coils were nearly approximated was no doubt very great. We conclude, then, that the length of the latency is largely influenced by the strength of stimulation, and an abridgement of the former of more than the $\frac{1}{100}$ of a second is readily produced by strong stimulation, without inflicting permanent injury upon the muscle. With stimulation of a much milder character, more closely related to physiological stimulation, a very slight shortening of the latency may be observed.

7. When Helmholtz was investigating the speed of motor nerve conductivity, he found that in the case of man this underwent a remarkable change in the summer time, so that its velocity became 60·50 metres per second, or fully twice as much as it had been some time previously. This acceleration he attributed to the elevation in atmospheric temperature occurring at that season, and this conclusion led him to a theory for the different speeds of conductivity in the upper arm when the nerve is sheltered and the lower when it is more superficial.

Troitzky, who investigated conduction in the nerve of the frog, stated that the speed was greatest between 10° and 20°, and diminished both under lower and higher temperatures.

It will be recollected that our moist chamber was furnished with a coil of tubing, which acted as means of producing heat or cold according to the temperature of the fluid passed through it; by means of this coil we were able to produce as extensive variations of heat or cold as our subject demanded. Water cooled by a mixture of chipped ice and salt in the one funnel, and water heated somewhat above the temperature we desired to produce in the other, enabled us by their conjoined use to hit the point we needed with precision. The attention of one of us was fixed upon the thermometer, and at a sign from him that the mercury stood at the desired level, the pendulum was liberated and the curve registered.

Some experiments were made to ascertain the effect upon exposed nerve of the temperature of the chamber, and with the results of these we will begin this section of our subject.

Our Table (VI) shows the effect of a depression of the temperature through 12° C. (from 17° to 5°) and of its subsequent elevation through 8° (17° to 25°) or of a total excursion through 20°. The variation of latency accompanying this change is from ·026″ (5°) to ·0127″ (25°), or no less than ·0133″ or the $\frac{1}{75}$ part of a second. Having taken a curve at the room temperature (17° C.), we rapidly cooled down the muscle to 5°, and then permitting it gradually to regain its normal a curve was taken at each degree; when 17° was reached we began to heat slowly till we had raised the temperature to 25°.

Table VI.—Effect of Heat and Cold on Gastrocnemius. Stimulation Indirect. Maximal.

No.	Weight.	Temp.	Length of latency.	Length of curve.	Altitude.	Remarks.
1	10 grms.	17° C.	2·9 d.v.	16·5 d.v.	22·5 mm.	
2	,,	5 ,,	4·7 ,,	33·25 ,,	22·0 ,,	
3	,,	6 ,,	4·5 ,,	32·5 ,,	22·0 ,,	
4	,,	7 ,,	4·25 ,,	31·5 ,,	22·0 ,,	
5	,,	8 ,,	4·05 ,,	29·75 ,,	21·0 ,,	
6	,,	9 ,,	4·4 ,,	25·0 ,,	21·0 ,,	
7	,,	10 ,,	3·85 ,,	23·0 ,,	21·0 ,,	
8	,,	11 ,,	3·75 ,,	22·0 ,,	20·0 ,,	
9	,,	12 ,,	3·5 ,,	21·25 ,,	19·5 ,,	
10	,,	13 ,,	3·35 ,,	20·0 ,,	19·0 ,,	
11	,,	14 ,,	3·25 ,,	18·25 ,,	19·0 ,,	Cooling below 12° causes a permanent shortening. The length of the active curve only given.
12	,,	15 ,,	3·2 ,,	17·25 ,,	20·0 ,,	
13	,,	16 ,,	2·9 ,,(?)	15·25 ,,	22·0 ,,	
14	,,	17 ,,	3·0 ,,	13·4 ,,	22·5 ,,	
15	,,	18 ,,	2·85 ,,	13·0 ,,	23·0 ,,	
16	,,	19 ,,	2·85 ,,	12·5 ,,	21·0 ,,	
17	,,	20 ,,	2·8 ,,	12·4 ,,	26·0 ,,	
18	,,	21 ,,	2·75 ,,	,,	25·0 ,,	
19	,,	22 ,,	2·7 ,,	,,	24·0 ,,	
20	,,	23 ,,	2·7 ,,	,,	24·25 ,,	
21	,,	24 ,,	2·5 ,,	12·25 ,,	24·25 ,,	
22	,,	25 ,,	2·30 ,,	12·25 ,,	24·25 ,,	

Let us examine the nature of the changes corresponding to our variations in temperature.

17°	......	2·9	15°	less	·05
5	......	4·7 or +1·8	16	,,	·3 (?)
6	less	·2	17	more	·1
7	,,	·25	18	less	·15
8	,,	·2	19	,,	·0
9	,,	·05	20	,,	·05
10	,,	·15	21	,,	·05
11	,,	·1	22	,,	·05
12	,,	·25	23	,,	·0
13	,,	·15	24	,,	·2
14	,,	·1	25	,,	·2

From these figures we see that the effect of cooling for equal degrees is greater than is the effect of heating; that is to say, that while cooling through 8 degrees adds 1 D.V. to the latency, heating through 8 degrees takes only ·7 D.V. away from it. The average effect for degree of cold is ·00069″, that of heat ·00048″, and could we take an average of the whole 12° through which cooling was carried, the figure would rise to ·00077″, because the addition of every degree of cold after 9° and 10° are reached, produces a more considerable elongation of latency.

If we carry the heating much above this point, we find that there is a sudden accession of excitability of the nerve as manifested by a much elevated and prolonged curve differing also in contour from its predecessors. This condition increases to a certain point, then diminishes, and the entire death of the nerve ensues. The first indication of danger occurs at about 27°, and death at 30°—31°. This muscle, however, may still be quite capable of responding to direct stimulation if the temperature be not further increased, and revives eventually. The following Table VII shows this course of events.

Table VII.—Heating carried to Death of Nerve with Measurement of Curves of Direct Stimulation subsequently taken.

No.	Weight.	Temp.	Length of latency.	Length of curve.	Altitude.	Remarks.
1	10 grms.	17° C.	3·10 d. v.	17·8 d. v.	24·5 mm.	
2	,,	18 ,,	2·95 ,,	16·7 ,,	25·0 ,,	
3	,,	19 ,,	2·75 ,,	16·1 ,,	26·0 ,,	
4	,,	20 ,,	2·55 ,,	15·8 ,,	32·5	
5	,,	21 ,,	2·45 ,,	16·1 ,,	33·0 ,,	
6	,,	22 ,,	2·2 ,,	16·2 ,,	34·5 ,,	
7	,,	23 ,,	2·15 ,,	15·8 ,,	35·5 ,,	
8	,,	24 ,,	2·15 ,,	15·8 ,,	36·5 ,,	
9	,,	25 ,,	2·15 ,,	15·8 ,,	35·5 ,,	
10	,,	26 ,,	2·1 ,,	15 0 ,,	31·5 ,,	
11	,,	27 ,,	2·0 ,,	17·4 ,,	42·0 ,,	Nerve irritable.
12	,,	28 ,,	2·0 ,,	18·9 ,,	54·0 ,,	
13	,,	29 ,,	9·05 ,,	19·0 ,,	56·0 ,,	
14	,,	30 ,,	2·15 ,,	18·5 ,,	55·0 ,,	
15	,,	31 ,,	2·2 ,,	19·0 ,,	50·5 ,,	
16	,,	32 ,,	0·0 ,,	0·0 ,,	0·0 ,,	Nerve dead.↑
17	,,	33 ,,	1·5 ,,	24·5 ,,	31·5 ,,	
18	,,	32 ,,	1·6 ,,	17·4 ,,	23·5 ,,	Stimulation of muscle
19	,,	31 ,,	1·65 ,,	13·0 ,,	20·0 ,,	

N.B.—The muscle completely recovered. A series of curves (direct stimulation) was subsequently taken from it.

Heating from 17°, at which the latency is 3·10 to 27°, reduces the latency to 2 D.V., and after this point there is again a slight increase till the death of the nerve at 31° occurs. That there is, however, a marked diminution of the latency from 20° to 27°, is plainly to be seen, as the variation is through ·003″, and this result scarcely coincides with the assumption that conductivity is impaired after 20° in the case of the frog.

The curarised muscle is a more fitting subject for the study of the influence of temperature than is the nerve-muscle preparation, as its mass prevents the extreme influences under which the delicate nerve suffers, being felt to such a large extent. The curve also is the expression of the actual effect of a certain temperature upon the muscle only instead of being that on both nerve and muscle. A rise or fall of temperature through a certain number of degrees has a magnified effect on the nerve-muscle preparation compared to what it has on the muscle.

Table VIII.—Cold and Heat on Curarised Gartroenemius.

No.	Weight.	Temp.	Length of latency.	Length. of curve.	Altitude.	Remarks.
1	10 grms.	19° C.	1 ·7 d. v.	14 ·0 d. v.	24 ·5 mm.	Extends below abscissa, single summit.
2	,,	18 ,,	1 ·8 ,,	14 ·8 ,,	24 ·5 ,,	Do. do.
3	,,	17 ,,	1 ·85 ,,	16 ·0 ,,	24 ·0 ,,	Reaches abscissa, single summit.
4	,,	13 ,,	2 ·0 ,,	20 ·0 ,,	25 ·0 ,,	Reaches abscissa, double summit.
5	,,	11 ,,	2 ·05 ,,	22 ·75 ,,	26 ·0 ,,	Does not touch abscissa, double summit.
6	,,	9 ,,	2 ·3 ,,	25 ·7 ,,	27 ·0 ,,	Do. do.
7	,,	7 ,,	2 ·5 ,,	38 ·0 ,,	30 ·0 ,,	Do. do.
8	,,	10 ,,	2 ·3 ,,	30 ·5 ,,	28 ·0 ,,	Do. do.
9	,,	12 ,,	2 ·1 ,,	25 ·0 ,,	27 ·5 ,,	Do. do.
10	,,	14 ,,	2 ·0 ,,	19 ·8 ,,	24 ·5 ,,	Almost touches abscissa, flat summit.
11	,,	16 ,,	1 ·75 ,,	15 ·4 ,,	25 ·5 ,,	Extends below abscissa, single summit.
12	,,	18 ,,	1 ·7 ,,	14 ·0 ,,	27 ,,	Do. do.
13	,,	20 ,,	1 ·6 ,,	13 ·4 ,,	27 ,,	Do. do.

We have before us the result of cooling a curarised muscle down from 19° to 7°, and then of heating it to 20°, and the figures represent fairly the changes in the curve and latency. The total addition to the latency is ·8 of a double vibration, or ·0044″ whilst the addition in the length of the curve is 24 D.V. The interesting fact is well demonstrated in this Table that the greater the influence of cooling through a given number of degrees has been upon the latency, the greater is the effect also on the curve, so that whereas between 19° and 17°, the latency varies the ·15 D.V., and the length of the curve increases only 2 D.V.'s between 9° and 7° where the latency increases ·2 D.V., the curve lengthens 13 D.V., but it is necessary to remember that it is exactly at this point 9—5°, that cold has such a powerful effect in prolonging the curve. The lengthening or shortening of latency and curve accompany each other with considerable precision, though it has appeared to us so far impossible to establish a constant and definite relationship between them for all temperatures and conditions.

Another result otained from the curarised muscle by heating to 30° after having cooled to 11°, shows the companionship of latency and curve in their variations.

Table IX.—Curarised Gastrocnemius exposed to Heat and Cold.

No.	Weight.	Temperature.	Latency.	Length.	Altitude.
1	10 grms.	11° C.	3·5 d. v.	30·0 d.v.	18·5 mm.
2	"	12 "	3·3 "	30·0 "	18·5 "
3	"	13 "	3·0 "	24·4 "	18·5 "
4	"	14 "	2·75 "	23·0 "	16·5 "
5	"	15 "	2·5 "	20·0 "	17·0 "
6	"	16 "	2·5 "	17·6 "	18·5 "
7	"	17 "	2·5 "	17·4 "	19·0 "
8	"	18 "	2·45 "	16·9 "	19·0 "
9	"	19 "	2·4 "	16·0 "	18·5 "
10	"	20 "	2·4 "	14·9 "	17·5 "
11	"	21 "	2·35 "	15·2 "	17·0 "
12	"	22 "	2·28 "	15·2 "	16·0 "
13	"	23 "	2·25 "	14·9 "	16·0 "
14	"	24 "	2·15 "	14·6 "	16·5 "
15	"	25 "	2·12 "	14·4 "	18·0 "
16	"	26 "	2·10 "	13·4 "	17·5 "
17	"	27 "	2·05 "	12·6 "	17·0 "
18	"	28 "	1·85 "	12·8 "	17·0 "
19	"	29 "	1·7 "	12·8 "	17·5 "
20	"	30 "	1·6 "	12·8 "	18·5 "

The latency varies through 1·9, the curve through 23·2 D.V. The extreme prolongation of the curve at 11° and 12° is an illustration of that which we think we have seen many times, though we have not found opportunity to work out the point, viz., that if after heating a muscle, the temperature be reduced below the normal, the effect of that reduction is greater in prolonging the latency and the curve than it would have been if starting from the normal only. The converse—for heating after cooling—appears also to hold good.

If a muscle be heated or cooled to a certain temperature and be maintained at that temperature for a considerable time, does the preparation acclimatize itself, and do latency and curve show a tendency to return towards the normal? Our answer is that they do not.

A muscle kept at 20° for 25′ gave a constant latency of 2·75 D.V., whilst the curve varied in value only through ·2 D.V.; at 25° for 15′ the latency remained at 1·65, the length of contraction varying only through ·3 D.V., the same result obtained on cooling.

We conclude then that cold lengthens and heat shortens the latency, the effect per degree of the former being greater than the latter. The shortest latency for the heated frog muscle occurs at 29—30·5°, and closely precedes rigor.

Muscles maintained for a considerable time at a given elevation or depression of temperature, preserve a constant latency.

Up to the present the gastrocnemius of the frog has been the only muscle upon which we have experimented, and our chief object in making this communication is to call attention to the changes in the duration of the latency brought about by varying conditions of stimulation. We hope to continue our observation by making similar experiments on different muscles of various animals, and in a future paper to enter more fully upon the changes occurring in the other phases of the contraction, for which purpose further use will be made of the tables we have the honour of laying before the Royal Society.

"Formulæ for sn 8*u*, cn 8*u*, dn 8*u*, in terms of sn *u*." By ERNEST H. GLAISHER, B.A., Trinity College, Cambridge. Communicated by J. W. L. GLAISHER, M.A., F.R.S. Received and Read June 16, 1881.

§ 1. In Grunert's "Archiv der Mathematik und Physik," vol. xxxvi (1861), pp. 125–176, Baehr has given the formulæ for sn *nu*, cn *nu*, dn *nu*, in terms of sn *u* for the cases $n=2, 3, 4, 5, 6, 7$. These expressions are reproduced by Cayley in a tabular form in his "Treatise on Elliptic Functions," Art. 109 (pp. 80–85).

The object of the present paper is to give the corresponding formulæ in the case of $n=8$. These were deduced from the formulæ for the case $n=4$ in the following manner.

We have

$$\operatorname{sn} 8u=\frac{2\operatorname{sn} 4u \operatorname{cn} 4u \operatorname{dn} 4u}{1-k^2 \operatorname{sn}^2 4u},$$

$$\operatorname{cn} 8u=\frac{1-2\operatorname{sn}^2 4u+k^2 \operatorname{sn}^4 4u}{1-k^2 \operatorname{sn}^2 4u},$$

$$\operatorname{dn} 8u=\frac{1-2k^2\operatorname{sn}^2 4u+k^2 \operatorname{sn}^4 4u}{1-k^2 \operatorname{sn}^2 4u},$$

and therefore, denoting the numerators of sn 4*u*, cn 4*u*, dn 4*u*, and their common denominator by P, Q, R, S respectively, so that

$$\operatorname{sn} 4u=\frac{P}{S}, \quad \operatorname{cn} 4u=\frac{Q}{S}, \quad \operatorname{dn} 4u=\frac{R}{S},$$

we find
$$\operatorname{sn} 8u=\frac{2PQRS}{S^4-k^2P^4},$$
$$\operatorname{cn} 8u=\frac{S^4-2P^2S^2+k^2P^4}{S^4-k^2P^4}$$
$$\operatorname{dn} 8u=\frac{S^4-2k^2P^2S^2+k^2P^4}{S^4-k^2P^4}.$$

§ 2. The numerators of sn $8u$, cn $8u$, dn $8u$, and their common denominator, may therefore be deduced by combining linearly the four expressions PQRS, P^4, S^4, P^2, S^2, where

$$P=x\sqrt{(1-x^2)}\sqrt{(1-k^2x^2)}\times \{4-(8+8k^2)x^2+20k^2x^4-20k^4x^8+(8k^4+8k^6)x^{10}-4k^6x^{12}\},$$
$$Q=1-8x^2+(8+20k^2)x^4-(24k^2+32k^4)x^6+(54k^4+16k^6)x^8 -(24k^4+32k^6)x^{10}+(8k^4+20k^6)x^{12}-8k^6x^{14}+k^8x^{16},$$
$$R=1-8k^2x^2+(20k^2+8k^4)x^4-(32k^2+24k^4)x^6+(16k^2+54k^4)x^8 -(32k^4+24k^6)x^{10}+(20k^6+8k^8)x^{12}-8k^8x^{14}+k^8x^{16},$$
$$S=1-20k^2x^4+(32k^2+32k^4)x^6-(16k^2+58k^4+16k^6)x^8 +(32k^4+32k^6)x^{10}-20k^6x^{12}+k^8x^{16},$$

and x denotes, as throughout this paper, sn u.

The values of PQRS, P^4, S^4, P^2S^2 were calculated in the following manner:

The squares P^2, S^2, and the products PS and QR, were first formed. Then P^2, S^2 were multiplied together, and the square of PS was formed: the agreement of these two results verified the values of P^2, S^2, P^2S^2. The expressions for P^4 and S^4 were then obtained by squaring P^2 and S^2; these calculations being performed in duplicate. To obtain PQRS the expressions for PS and QR were multiplied together; and as a verification the product PQ was formed, and this was multiplied successively by S and R.

§ 3. The resulting formulæ are shown in the following tables, in which the mode of arrangement is almost obvious: thus, for example, the numerator of sn $8u$.

$$\begin{aligned}&=x\sqrt{\{(1-x^2)(1-k^2x^2)\}}\times\\ &\quad\{8\\ &\quad-(80+80k^2)x^2\\ &\quad+(192+968k^2+192k^4)x^4\\ &\quad-(128+2496k^2+2496k^4+128k^6)x^6\\ &\quad+(1728k^2-7416k^4+1728k^6)x^8\\ &\quad+(87984k^4+87984k^6)x^{10}\\ &\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\\ &\quad+(80k^{28}+80k^{30})x^{58}\\ &\quad-8k^{30}x^{60}\}\end{aligned}$$

Numerator of $\operatorname{sn} 8u = x\sqrt{\{(1-x^2)(1-k^2x^2)\}} \times$

	k^0.	k^2.	k^4.	k^6.	k^8.	k^{10}.	k^{12}.	k^{14}.
$x^0 k^0$	+ 8							
$x^2 k^0$	− 80	− 80						
$x^4 k^0$	+ 192	+ 968	+ 192					
$x^6 k^0$	− 128	− 2496	− 2496	− 128				
$x^8 k^2$	+ 1728	− 7416	+ 1728					
$x^{10} k^4$	+ 87984	+ 87984						
$x^{12} k^4$	− 274176	− 645048	− 274176					
$x^{14} k^4$	+ 496128	+ 2049792	+ 2049792	+ 496128				
$x^{16} k^4$	− 583680	− 3954432	− 6962136	− 3954432	− 583680			
$x^{18} k^4$	+ 430080	+ 4915200	+ 14388720	+ 14388720	+ 4915200	+ 430080		
$x^{20} k^4$	− 180224	− 3794944	− 18971200	− 31859224	− 18971200	− 3794944	− 180224	
$x^{22} k^4$	+ 32768	+ 1654784	+ 15392128	+ 44633920	+ 44633920	+ 15392128	+ 1654784	+ 32768
$x^{24} k^6$	− 311296	− 6998016	− 38113344	− 65268568	− 38113344	− 6998016	− 311296	
$x^{26} k^8$	+ 1363968	+ 18087936	+ 55747056	+ 55747056	+ 18087936	+ 1363968		
$x^{28} k^{10}$	− 3655680	− 23083008	− 40128024	− 23083008	− 3655680			
x^{30}	0							
$x^{32} k^{12}$	+ 3655680	+ 23083008	+ 40128024	+ 23083008	+ 3655680			
$x^{34} k^{12}$	− 1363968	− 18087936	− 55747056	− 55747056	− 18087936	− 1363968		
$x^{36} k^{12}$	+ 311296	+ 6998016	+ 38113344	+ 65268568	+ 38113344	+ 6998016	+ 311296	
$x^{38} k^{12}$	− 32768	− 1654784	− 15392128	− 44633920	− 44633920	− 15392128	− 1654784	− 32768
$x^{40} k^{14}$	+ 180224	+ 3794944	+ 18971200	+ 31859224	+ 18971200	+ 3794944	+ 180224	
$x^{42} k^{16}$	− 430080	− 4915200	− 14388720	− 14388720	− 4915200	− 430080		
$x^{44} k^{18}$	+ 583680	+ 3954432	+ 6962136	+ 3954432	+ 583680			
$x^{46} k^{20}$	− 496128	− 2049792	− 2049792	− 496128				
$x^{48} k^{22}$	+ 274176	+ 645048	+ 274176					
$x^{50} k^{24}$	− 87984	− 87984						
$x^{52} k^{24}$	− 1728	+ 7416	− 1728					
$x^{54} k^{24}$	+ 128	+ 2496	+ 2496	+ 128				
$x^{56} k^{26}$	− 192	− 968	− 192					
$x^{58} k^{28}$	+ 80	+ 80						
$x^{60} k^{30}$	− 8							

Numerator of cn $8u$ =

	k^0.	k^2.	k^4.	k^6.	k^8.	k^{10}.	k^{12}.
$x^0 k^0$	+ 1						
$x^2 k^0$	− 32						
$x^4 k^0$	+ 160	+ 336					
$x^6 k^0$	− 256	− 2016	− 2688				
$x^8 k^0$	+ 128	+ 3456	+ 21816	+ 10560			
$x^{10} k^2$	− 1792	− 77088	− 99968	− 22528			
$x^{12} k^4$	+ 209888	+ 435440	+ 234240	+ 26624			
$x^{14} k^4$	− 470016	− 1448672	− 1135872	− 294912	− 16384		
$x^{16} k^4$	+ 744192	+ 3642624	+ 4407964	+ 1529472	+ 189952	+ 4096	
$x^{18} k^4$	− 778240	− 6206464	− 12575904	− 7406848	− 1032192	− 49152	
$x^{20} k^4$	+ 516096	+ 6885376	+ 23453856	+ 25350480	+ 8029952	+ 276480	
$x^{22} k^4$	− 196608	− 4792320	− 27864320	− 53121888	− 35957120	− 7092224	
$x^{24} k^4$	+ 32768	+ 1900544	+ 20467584	+ 68399744	+ 87045768	+ 41956032	+ 5990400
$x^{26} k^6$	− 327680	− 8478720	− 53349120	− 124358560	− 115922304	− 40808448	− 4128768
$x^{28} k^8$	+ 1515520	+ 23162880	+ 107670240	+ 184895600	+ 122807808	+ 29483008	+ 1900544
$x^{30} k^{10}$	− 4300800	− 55238656	− 183281760	− 214341120	− 93880320	− 14155776	− 524288
$x^{32} k^{12}$	+ 16755200	+ 118052352	+ 239133510	+ 175676160	+ 47342592	+ 4055040	+ 65536
$x^{34} k^{12}$	− 4300800	− 55238656	− 183281760	− 214341120	− 93880320	− 14155776	− 524288
$x^{36} k^{12}$	+ 1515520	+ 23162880	+ 107670240	+ 184895600	+ 122807808	+ 29483008	+ 1900544
$x^{38} k^{12}$	− 327680	− 8478720	− 53349120	− 124358560	− 115922304	− 40808448	− 4128768
$x^{40} k^{12}$	+ 32768	+ 1900544	+ 20467584	+ 68399744	+ 87045768	+ 41956032	+ 5990400
$x^{42} k^{14}$	− 196608	− 4792320	− 27864320	− 53121888	− 35957120	− 7092224	
$x^{44} k^{16}$	+ 516096	+ 6885376	+ 23453856	+ 25350480	+ 8029952	+ 276480	
$x^{46} k^{18}$	− 778240	− 6206464	− 12575904	− 7406848	− 1032192	− 49152	
$x^{48} k^{20}$	+ 744192	+ 3642624	+ 4407964	+ 1529472	+ 189952	+ 4096	
$x^{50} k^{22}$	− 470016	− 1448672	− 1135872	− 294912	− 16384		
$x^{52} k^{24}$	+ 209888	+ 435440	+ 234240	+ 26624			
$x^{54} k^{24}$	− 1792	− 77088	− 99968	− 22528			
$x^{56} k^{24}$	+ 128	+ 3456	+ 21816	+ 10560			
$x^{58} k^{26}$	− 256	− 2016	− 2688				
$x^{60} k^{28}$	+ 160	+ 336					
$x^{62} k^{30}$	− 32						
$x^{64} k^{32}$	+ 1						

Numerator of dn $8u$=

	k^0.	k^4.	k^6.	k^8.	k^{10}.	k^{12}.	k^{14}.
$x^0 k^0$	+ 1						
$x^2 k^2$	− 32						
$x^4 k^2$	+ 336	+ 160					
$x^6 k^2$	− 2688	− 2016	− 256				
$x^8 k^2$	+ 10560	+ 21816	+ 3456	+ 128			
$x^{10} k^2$	− 22528	− 99968	− 77088	− 1792			
$x^{12} k^2$	+ 26624	+ 234240	+ 435440	+ 209888			
$x^{14} k^2$	− 16384	− 294912	− 1135872	− 1448672	− 470016		
$x^{16} k^2$	+ 4096	+ 189952	+ 1529472	+ 4407964	+ 3642624	+ 744192	
$x^{18} k^4$	− 49152	− 1032192	− 7406848	− 12575904	− 6206464	− 778240	
$x^{20} k^6$	+ 276480	+ 8029952	+ 25350480	+ 23453856	+ 6885376	+ 516096	
$x^{22} k^8$	− 7092224	− 35957120	− 53121888	− 27864320	− 4792320	− 196608	
$x^{24} k^8$	+ 5990400	+ 41956032	+ 87045768	+ 68399744	+ 20467584	+ 1900544	+ 32768
$x^{26} k^8$	− 4128768	− 40808448	− 115922304	− 124358560	− 53349120	− 8478720	− 327680
$x^{28} k^8$	+ 1900544	+ 29483008	+ 122807808	+ 184895600	+ 107670240	+ 23162880	+ 1515520
$x^{30} k^8$	− 524288	− 14155776	− 93880320	− 214341120	− 183281760	− 55238656	− 4300800
$x^{32} k^8$	+ 65536	+ 4055040	+ 47342592	+ 175676160	+ 239133510	+ 118052352	+ 16755200
$x^{34} k^{10}$	− 524288	− 14155776	− 93880320	− 214341120	− 183281760	− 55238656	− 4300800
$x^{36} k^{12}$	+ 1900544	+ 29483008	+ 122807808	+ 184895600	+ 107670240	+ 23162880	+ 1515520
$x^{38} k^{14}$	− 4128768	− 40808448	− 115922304	− 124358560	− 53349120	− 8478720	− 327680
$x^{40} k^{16}$	+ 5990400	+ 41956032	+ 87045768	+ 68399744	+ 20467584	+ 1900544	+ 32768
$x^{42} k^{18}$	− 7092224	− 35957120	− 53121888	− 27864320	− 4792320	− 196608	
$x^{44} k^{18}$	+ 276480	+ 8029952	+ 25350480	+ 23453856	+ 6885376	+ 516096	
$x^{46} k^{18}$	− 49152	− 1032192	− 7406848	− 12575904	− 6206464	− 778240	
$x^{48} k^{18}$	+ 4096	+ 189952	+ 1529472	+ 4407964	+ 3642624	+ 744192	
$x^{50} k^{20}$	− 16384	− 294912	− 1135872	− 1448672	− 470016		
$x^{52} k^{22}$	+ 26624	+ 234240	+ 435440	+ 209888			
$x^{54} k^{24}$	− 22528	− 99968	− 77088	− 1792			
$x^{56} k^{26}$	+ 10560	+ 21816	+ 3456	+ 128			
$x^{58} k^{28}$	− 2688	− 2016	− 256				
$x^{60} k^{30}$	+ 336	+ 160					
$x^{62} k^{32}$	− 32						
$x^{64} k^{32}$	+ 1						

The Common Denominator=

	k^0.	k^2.	k^4.	k^6.	k^8.	k^{10}.	k^{12}.	k^{14}.	k^{16}.
$x^0 k^0$	+ 1								
x^2	0								
$x^4 k^2$	− 336								
$x^6 k^2$	+ 2688	+ 2688							
$x^8 k^2$	− 10560	− 24456	− 10560						
$x^{10} k^2$	+ 22528	+ 105600	+ 105600	+ 22528					
$x^{12} k^2$	− 26624	− 240896	− 498160	− 240896	− 26624				
$x^{14} k^2$	+ 16384	+ 299008	+ 1212160	+ 1212160	+ 299008	+ 16384			
$x^{16} k^2$	− 4096	− 190976	− 1577600	− 2859236	− 1577600	− 196976	− 4096		
$x^{18} k^4$	+ 49152	+ 1044480	+ 2750208	+ 2750208	+ 1044480	+ 49152			
$x^{20} k^6$	− 276480	+ 968448	+ 3136944	+ 968448	− 276480				
$x^{22} k^8$	− 5154816	− 20678784	− 20678784	− 5154816					
$x^{24} k^8$	+ 5990400	+ 38714688	+ 68067144	+ 38714688	+ 5990400				
$x^{26} k^8$	− 4128768	− 41840640	− 118173312	− 118173312	− 41840640	− 4128768			
$x^{28} k^8$	+ 1900544	+ 29958144	+ 130475520	+ 208436624	+ 130475520	+ 29958144	+ 1900544		
$x^{30} k^8$	− 524288	− 14286848	− 97501184	− 240084480	− 240084480	− 97501184	− 14286848	− 524288	
$x^{32} k^8$	+ 65536	+ 4071424	+ 48366592	+ 188153088	+ 290931270	+ 188153088	+ 48366592	+ 4071424	+ 65536
$x^{34} k^{10}$	− 524288	− 14286848	− 97501184	− 240084480	− 240084480	− 97501184	− 14286848	− 524288	
$x^{36} k^{12}$	+ 1900544	+ 29958144	+ 130475520	+ 208436624	+ 130475520	+ 29958144	+ 1900544		
$x^{38} k^{14}$	− 4128768	− 41840640	− 118173312	− 118173312	− 41840640	− 4128768			
$x^{40} k^{16}$	+ 5990400	+ 38714688	+ 68067144	+ 38714688	+ 5990400				
$x^{42} k^{18}$	− 5154816	− 20678784	− 20678784	− 5154816					
$x^{44} k^{18}$	− 276480	+ 968448	+ 3136944	+ 968448	− 276480				
$x^{46} k^{18}$	+ 49152	+ 1044480	+ 2750208	+ 2750208	+ 1044480	+ 49152			
$x^{48} k^{18}$	− 4096	− 190976	− 1577600	− 2859236	− 1577600	− 190976	− 4096		
$x^{50} k^{20}$	+ 16384	+ 299008	+ 1212160	+ 1212160	+ 299008	+ 16384			
$x^{52} k^{22}$	− 26624	− 240896	− 498160	− 240896	− 26624				
$x^{54} k^{24}$	+ 22528	+ 105600	+ 105600	+ 22528					
$x^{56} k^{26}$	− 10560	− 24456	− 10560						
$x^{58} k^{28}$	+ 2688	+ 2688							
$x^{60} k^{30}$	− 336								
x^{62}	0								
$x^{64} k^{32}$	+ 1								

§ 4. If k be put equal to unity the cn and dn become identical, and the formulæ, as is well known, assume the simple forms

$$\operatorname{sn} nu = \frac{(1+x)^n-(1-x)^n}{(1+x)^n+(1-x)^n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (k=1),$$

$$\operatorname{cn} nu = \frac{2(1-x^2)^{\frac{1}{2}n}}{(1+x)^n+(1-x)^n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (k=1).$$

Putting $n=8$ in these formulæ, we have

$$\operatorname{sn} 8u = \frac{8(x+7x^3+7x^5+x^7)}{1+28x^2+70x^4+28x^6+x^8},$$

$$\operatorname{cn} 8u = \frac{1-4x^2+6x^4-4x^6+x^8}{1+28x^2+70x^4+28x^6+x^8}.$$

When k is put equal to 1 the formulæ in § 3 should reduce to these expressions: and we thus obtain an important verification of their accuracy.

Since the denominator of sn $8u$, cn $8u$, dn $8u$ is of the order 64 in x, it is evident that a factor of the order 56 is common to the numerator and denominator of these expressions when k is put equal to unity. By putting $k=1$ in the formulæ of § 3 and dividing the resulting expression for the numerator of sn $8u$ by $1+7x^2+7x^4+x^6$ it is found that this factor is $(1-x^2)^{28}$, as it should be. And it was verified by division that the expressions for the numerator of cn $8u$ and the common denominator were equal to this factor multiplied by $1-4x^2+6x^4-4x^6+x^8$ and $1+28x^2+70x^4+28x^6+x^8$ respectively.

§ 5. The expressions P^2, S^2, P^4, S^4 are respectively the numerators and denominators of $\operatorname{sn}^2 u$ and of $\operatorname{sn}^4 u$, and it seems worth while to place on record their values, which are as follows:

$P^2 =$

	k^0.	k^2.	k^4.	k^6.
$x^2 k^0$	+ 16			
$x^4 k^0$	− 80	− 80		
$x^6 k^0$	+ 128	+ 432	+ 128	
$x^8 k^0$	− 64	− 736	− 736	− 64
$x^{10} k^2$	+ 384	+ 1168	+ 384	
$x^{12} k^4$	− 176	− 176		
$x^{14} k^4$	− 512	− 1616	− 512	
$x^{16} k^4$	+ 128	+ 1984	+ 1984	+ 128
$x^{18} k^6$	− 512	− 1616	− 512	
$x^{20} k^8$	− 176	− 176		
$x^{22} k^8$	+ 384	+ 1168	+ 384	
$x^{24} k^8$	− 64	− 736	− 736	+ 64
$x^{26} k^{10}$	+ 128	+ 432	+ 128	
$x^{28} k^{12}$	− 80	− 80		
$x^{30} k^{14}$	+ 16			

$S^2 =$

	k^0.	k^2.	k^4.	k^6.	k^8.
$x^0 k^0$	+ 1				
x^2	0				
$x^4 k^2$	− 40				
$x^6 k^2$	+ 64	+ 64			
$x^8 k^2$	− 32	+ 284	− 32		
$x^{10} k^4$	− 1216	− 1216			
$x^{12} k^4$	+ 1664	+ 4328	+ 1664		
$x^{14} k^4$	− 1024	− 6016	− 6016	− 1024	
$x^{16} k^4$	+ 256	+ 3904	+ 8774	+ 3904	+ 256
$x^{18} k^6$	− 1024	− 6016	− 6016	− 1024	
$x^{20} k^8$	+ 1664	+ 4328	+ 1664		
$x^{22} k^{10}$	− 1216	− 1216			
$x^{24} k^{10}$	− 32	+ 284	− 32		
$x^{26} k^{12}$	+ 64	+ 64			
$x^{28} k^{14}$	− 40				
x^{30}	0				
$x^{32} k^{16}$	+ 1				

$P^4 =$

	k^0.	k^2.	k^4.	k^6	k^8.	k^{10}.	k^{12}.
$x^4 k^0$	+ 256						
$x^6 k^0$	− 2560	− 2560					
$x^8 k^0$	+ 10496	+ 26624	+ 10496				
$x^{10} k^0$	− 22528	− 113152	− 113152	− 22528			
$x^{12} k^0$	+ 26624	+ 250880	+ 492288	+ 250880	+ 26624		
$x^{14} k^0$	− 16384	− 305152	− 1094656	− 1094656	− 305152	− 16384	
$x^{16} k^0$	+ 4096	+ 192512	+ 1278464	+ 2301952	+ 1278464	+ 192512	+ 4096
$x^{18} k^2$	− 49152	− 673792	− 2126848	− 2126848	− 673792	− 49152	
$x^{20} k^4$	+ 18432	− 31744	− 167680	− 31744	+ 18432		
$x^{22} k^4$	+ 98304	+ 1525760	+ 5241344	+ 5241344	+ 1525760	+ 98304	
$x^{24} k^4$	− 16384	− 966656	− 6584576	− 11937792	− 6584576	− 966656	− 16384
$x^{26} k^6$	+ 163840	+ 2854912	+ 9734656	+ 9734656	+ 2854912	+ 163840	
$x^{28} k^8$	− 45056	− 481280	− 849152	− 481280	− 45056		
$x^{30} k^8$	− 196608	− 3379200	− 11638784	− 11638784	− 3379200	− 196608	
$x^{32} k^8$	+ 24576	+ 1548288	+ 11115520	+ 20267008	+ 11115520	+ 1548288	+ 24576
$x^{34} k^{10}$	− 196608	− 3379200	− 11638784	− 11638784	− 3379200	− 196608	
$x^{36} k^{12}$	− 45056	− 481280	− 849152	− 481280	− 45056		
$x^{38} k^{12}$	+ 163840	+ 2854912	+ 9734656	+ 9734656	+ 2854912	+ 163840	
$x^{40} k^{12}$	− 16384	− 966656	− 6584576	− 11937792	− 6584576	− 966656	− 16384
$x^{42} k^{14}$	+ 98304	+ 1525760	+ 5241344	+ 5241344	+ 1525760	+ 98304	
$x^{44} k^{16}$	+ 18432	− 31744	− 167680	− 31744	+ 18432		
$x^{46} k^{16}$	− 49152	− 673792	− 2126848	− 2126848	− 673792	− 49152	
$x^{48} k^{16}$	+ 4096	+ 192512	+ 1278464	+ 2301952	+ 1278464	+ 192512	+ 4096
$x^{50} k^{13}$	− 16384	− 305152	− 1094656	− 1094656	− 305152	− 16384	
$x^{52} k^{20}$	+ 26624	+ 250880	+ 492288	+ 250880	+ 26624		
$x^{54} k^{22}$	− 22528	− 113152	− 113152	− 22528			
$x^{56} k^{24}$	+ 10496	+ 26624	+ 10496				
$x^{58} k^{26}$	− 2560	− 2560					
$x^{60} k^{28}$	+ 256						

$S^4 =$

	k^0.	k^2.	k^4.	k^6.	k^8.	k^{10}.	k^{12}.	k^{14}.	k^{16}.
$x^0 k^0$	+ 1								
x^2									
$x^4 k^2$	− 80								
$x^6 k^2$	+ 128	+ 128							
$x^8 k^2$	− 64	+ 2168	− 64						
$x^1 k^4$	− 7552	− 7552							
$x^1 k$	+ 9984	− 5872	+ 9984						
$x^{14} k^4$	− 6144	+ 117504	+ 117504	− 6144					
$x^{16} k^4$	+ 1536	− 299136	− 557284	− 299136	+ 1536				
$x^{18} k^6$	+ 370688	+ 623360	+ 623360	+ 370688					
$x^{20} k^6$	− 258048	+ 936704	+ 2969264	+ 936704	− 258048				
$x^{22} k^6$	+ 98304	− 3629056	− 15437440	− 15437440	− 3629056	+ 98304			
$x^{24} k^6$	− 16384	+ 5023744	+ 32130112	+ 56129352	+ 32130112	+ 5023744	− 16384		
$x^{26} k^8$	− 3964928	− 38985728	− 108438656	− 108438656	− 38985728	− 3964928			
$x^{28} k^8$	+ 1900544	+ 29913088	+ 129994240	+ 207587472	+ 129994240	+ 29913088	+ 1900544		
$x^{30} k^8$	− 524288	− 14483456	− 100880384	− 251723264	− 251723264	− 100880384	− 14483456	− 524288	
$x^{32} k^8$	+ 65536	+ 4096000	+ 49914880	+ 199268608	+ 311198278	+ 199268608	+ 49914880	+ 4096000	+ 65536
$x^{34} k^{10}$	− 524288	− 14483456	− 100880384	− 251723264	− 251723264	− 100880384	− 14483456	− 524288	
$x^{36} k^{12}$	+ 1900544	+ 29913088	+ 129994240	+ 207587472	+ 129994240	+ 29913088	+ 1900544		
$x^{38} k^{14}$	− 3964928	− 38985728	− 108438656	− 108438656	− 38985728	− 3964928			
$x^{40} k^{14}$	− 16384	+ 5023744	+ 32130112	+ 56129352	+ 32130112	+ 5023744	− 16384		
$x^{42} k^{16}$	+ 98304	− 3629056	− 15437440	− 15437440	− 3629056	+ 98304			
$x^{44} k^{18}$	− 258048	+ 936704	+ 2969264	+ 936704	− 258048				
$x^{46} k^{20}$	+ 370688	+ 623360	+ 623360	+ 370688					
$x^{48} k^{20}$	+ 1536	− 299136	− 557284	− 299136	+ 1536				
$x^{50} k^{22}$	− 6144	+ 117504	+ 117504	− 6144					
$x^{52} k^{24}$	+ 9984	− 5872	+ 9984						
$x^{54} k^{26}$	− 7552	− 7552							
$x^{56} k^{26}$	− 64	+ 2168	− 64						
$x^{58} k^{28}$	+ 128	+ 128							
$x^{60} k^{30}$	− 80								
x^{62}									
$x^{64} k^{32}$	+ 1								

"On the Influence of Coal-dust in Colliery Explosions. No. III." By W. Galloway. Received May 30, Read June 16, 1881.* Revised February 10, 1882.

[Plate 4.]

In September of last year (1880) I commenced a new series of experiments with coal-dust with a larger apparatus than the one described at p. 416, vol. 28 of the "Proceedings." Excepting the difference of scale, however, the two sets of apparatus are nearly the same in construction, and they are identical as far as the experiment is concerned.

A photograph accompanying the paper, and remaining in the hands of the Royal Society, represents the apparatus as it stands ready for work at Llwynypia Colliery. Its principal details may be sufficiently understood from a verbal description; they are as follows:—

A. The explosion chamber, about 6 feet long by 2 feet in diameter; lined with thin strips of wood round about its circumference; with two openings, a and a', in its upper side, the first for admitting fire-damp, the second for igniting the mixture; a third opening nearly below a' for letting out the air displaced by the fire-damp is not visible. Internally it is provided with a small centrifugal fan, which draws the air and gas from the farther end of the cylinder through a pipe 4 inches in diameter, and concentric with the cylinder, and ejects it round its periphery at the nearer end, where it is situated. This mixes the air and gas. The cylinder rests on a carriage with wheels, and can be drawn back from or brought close up to the rectangular chamber, B, to which it can be fastened by means of four bolts.

B. The gallery, about 126 feet long by 2 feet square inside, made of wood, consisting of seven pieces, each 18 feet long, placed end to end. The separate pieces are hooped with iron bands, and one side of each can be opened like a door 18 feet long by 2 feet 3 inches wide, with horizontal hinges. The iron hoops are so arranged that they constitute hinges, hasps, and locking-bolts for the doors at the same time.

C. The measuring cylinder; its upper end is connected with the explosion chamber, on the one hand, by means of the india-rubber tube attached at the point a, and with the fire-damp pipe on the other hand by means of the tube b; its lower end is connected to the bottom of the vessel D by means of the flexible pipe c; it is provided with three stop-cocks and a water-gauge.

D. A vessel that can be raised above or lowered below the level of the measuring cylinder by means of a windlass, F, with a rope passing over the pulley, d, and attached to the bow at its top.

* See Abstract, vol. 33, p. 454.

E. A small air-fan driven by a steam turbine.

F. The windlass.

G. A grooved wheel for driving the fan inside the explosion chamber by means of an endless cord that passes over a small grooved pulley in the centre of the end of that chamber.

H. The fire-damp pipe.

K. The steam pipe.

When the vessel D is full of water and raised to the point it occupies in the drawing, its contents flow into the measuring vessel C, and expel the air contained in it. The vessel D is then lowered until its top is under the level of the bottom of the measuring cylinder, and the water flows back out of the latter into the former; and when the upper end of the measuring cylinder is in communication with the fire-damp pipe it fills with that gas. By raising the vessel D again to the position occupied at first, the fire-damp can be expelled and driven into the explosion chamber at *a*.

Following are the various operations that require to be performed before an experiment is made:—The explosion chamber is drawn back and several sheets of paper are inserted between it and the gallery, so as to form a diaphragm between them. They are then bolted together, and the quantity of fire-damp required to produce the most explosive mixture is forced into the explosion chamber from the measuring cylinder, at the same time that a corresponding quantity of air is allowed to flow out below. The lower opening is then plugged, and the wheel G is revolved 100 times. Meanwhile the fan E can be supplying heated air to the gallery through the channel which connects them; but in my later experiments I have not found that this affects the result to an appreciable extent. The side which constitutes the door of each section of the gallery is raised in succession, and coal-dust is strewed on the floor to a thickness of $\frac{1}{8}$ to $\frac{1}{4}$ inch; some is also laid on shelves, which are placed in sets of three, one above the other, at distances varying from 10 to 20 feet apart.

When the floor is made damp with water, so as to fix every particle of dust that cannot be swept out with a brush, the flame of the fire-damp explosion travels along the gallery to a distance of 12 feet on the average. When the gallery contains coal-dust, on the other hand, the explosion of the fire-damp raises it in a cloud, and the flame appears to travel as far as the cloud contains more than a certain minimum amount of dust, and then to die out for want of fuel. A fair average distance is 70 feet, but it occasionally reaches 80 and 85 feet, and on one occasion it extended to 104 feet. The natural supply of fire-damp is too limited to admit of the creation of an atmosphere with an appreciable proportion of fire-damp in the interior of the gallery, so that all the experiments have been made with pure air hitherto; and, further, as I have already mentioned, I do not find that heating the air to a temperature of 70° or 80° Fahr. makes any difference in the result, so that I have discontinued to do so in the more recent experiments.

With this apparatus, as with the smaller one described in my previous paper, of which it is a copy, the inertia and frictional resistance of the air filling the gallery appears to be a factor of considerable importance. For instance, if the whole of the sections are closed, making the gallery continuous throughout its whole length of 126 feet, the flame of the coal-dust does not reach further than 50 or 60 feet from the origin; but if the sides of the fourth and fifth sections are open, making the closed portion only 54 feet long, and leaving 36 feet with only three sides, the flame will, as a rule, be 70 feet and sometimes 80 and 90 feet long. The flame of the coal-dust appears to be self-supporting in pure air, but it cannot keep up the disturbance necessary to supply itself with fuel on this small scale, and, consequently, it cannot get much beyond the point to which the more energetic action of the fire-damp explosion has extended. I will not pursue this subject further at present, as it is my intention to continue the experiments, and I hope to have another opportunity of stating the results.

Three great colliery explosions took place during the year 1880, namely, Risca on the 15th of July, with a loss of 120 lives; Seaham on the 8th of September, with a loss of 164 lives; and Penygraig on the 10th of December, with a loss of 101 lives. For the purpose of the present paper I visited Risca Colliery on the 24th of October, and Seaham Colliery on the 24th of November of the same year. I had also an excellent opportunity of acquiring an intimate knowledge of the details of Penygraig explosion, having been* entrusted with the direction of the exploring operations, and having visited the workings twice within the first twenty-four hours after its occurrence, and several times at a later period. The workings of each of these mines were dry, and their roadways were covered with dry coal-dust, from the faces at which the coal was worked to the bottom of the upcast and downcast shafts; but, with the exception of making this general remark regarding them, I do not propose, in this place, further to refer to the Risca or Seaham explosions.

At Penygraig Colliery I made three principal sets of observations which have not, I believe, been made in any previous case of the kind, and they appear to throw a considerable amount of light on the nature of the accident. They were as follows:—

1. The flame of the explosion *had passed through or penetrated into every part of the workings* with the exception of one wet heading *d* (see the accompanying plan) at the bottom of the downcast shaft.

* It should be mentioned in this place that I had no connexion with or knowledge of Penygraig Colliery before the explosion took place.

Four of the five men who escaped with their lives were in the heading *d* at the time of the explosion. They saw the flash, but were not burnt. The fifth, who was working in a *cul de sac* at *e*, was slightly burnt, and remained unconscious for many hours. The unshaded galleries on the plan, except *d*, show the universal distribution of the flame, which must also be supposed to have passed over the ground covered by falls of roof due to the explosion. The shaded patches show the points at which the evidence of a high temperature, such as really charred timber and thick deposits of coked coal-dust, were strongest. It will be seen that each of these points was either in a *cul de sac*, or was approachable from two opposite directions.

2. Five or six of the seventeen bodies found between the points *b* and *e* in the main heading *were in a kneeling posture, their mouths were covered with their hands, and their faces were pressed into the dust on the floor.* One body in the roadway *l* was *in the same position;* another near him was lying on his side *with his coat drawn closely over his mouth and nose, and held tightly with one hand;* and a third, lying at the opposite side of the roadway, *had his mouth pressed on the ground*, his head having been twisted round to some extent so as to admit of this. I observed that two of the first group and the three constituting the last group had been burnt *after they had assumed these positions*, but unfortunately I did not particularly examine the others, as they had been removed before the true significance of these circumstances had dawned upon me.

3. There were deposits, or crusts, of coked coal-dust in every *working place* in the mine (from the district with the two small arrow-heads above the upcast shaft to the district *g* above the downcast shaft at the opposite extremity), that is to say, *where the coal-dust was comparatively free from impurities*, and capable of adhering to the timber and other objects when thrown against them in a fluid or semi-fluid state. On the other hand, the same kind of deposits were very rare, and for the most part entirely absent, in the main roadways through which the flame must necessarily have passed in travelling from one district to another, that is to say, *where the coal-dust was largely mixed with shale-dust and other impurities*, and consequently incapable of cohering when heated.

The following table of analyses which the late Professor A. Freire-Marreco, of Newcastle-on-Tyne, kindly prepared for me, shows the composition of the coal itself, that of the dust from the floor, &c., and that of the so-called coked coal-dust.

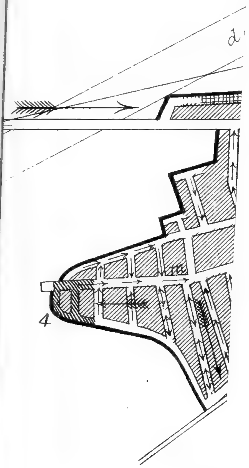
Each number on the table corresponds to the same number on the plan, which indicates the spot at which the sample in question was collected.

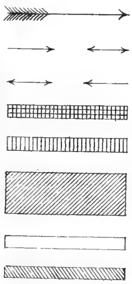
Position on the plan.	Description of the Sample.	Moisture and volatile matter.	Ash.
1	Penygraig coal...........................	18·66	2·05
2	Dust from the floor of the main heading....	17·67	22·20
2A	Residue after sifting out 2 through muslin..	18·91	31·10
3	Coked coal-dust from a prop at the face....	15·29	6·61
4	Exceedingly light, hollow, brittle vesicles of a black shining substance found adhering as a thin skin to the roof over the whole shaded space at (4). The vesicles were thickly studded all over the same space, and hung down from the roof, like pendants, $\frac{1}{4}$ to $\frac{3}{4}$ inch long	18·31	6·00
5	Dust brushed from a prop: no coked crusts near	15·67	23·94
6	Dust brushed from a ledge of rock: no coke near	14·94	25·60
7	Dust brushed from large stones on the floor: no coked crusts near..................	14·45	29·67
8	Shale constituting the roof of the seam	8·46	92·56
8A	Brittle shale that falls with the coal, varying in thickness from $\frac{1}{2}$ inch to 3 inches......	10·65	77·08
8B	Shale constituting the floor of the seam	10·14	82·57

The small black single-headed arrows show the direction in which the deposits of coked coal-dust were thrown against the objects to which they were found adhering. The double-headed arrows show that it had been thrown against the same objects from two sides, probably first from one side and then from the other. It should be carefully noted that, as a rule, the arrows point away from the solid ground, and consequently in a direction contrary to that in which the blast must of necessity have travelled in passing through or into every working place in the colliery, except the one in which the explosion originated. It must, therefore, have been deposited *during the retrograde movement of the air*, and this corresponds to the observation I had previously made at Llan Colliery in regard to the same phenomenon ("Proc. Roy. Soc.," vol. 24, p. 359). If these deposits were to be found everywhere in the workings, and if the currents which produced them were not liable to baffling and reversal from local circumstances, it is obvious that the arrows showing the direction in which they had been thrown would nearly all point backwards to the spot at which the explosion had originated. Although differences of opinion were expressed as to the causes of the explosion in the case before us, it was admitted on all hands that it had probably originated somewhere in the neighbourhood of the point *o*.

Lastly, although the existence of accumulations of explosive gas appears to have been almost unknown in the mine, there could be no doubt that a very large amount of fire-damp was being constantly

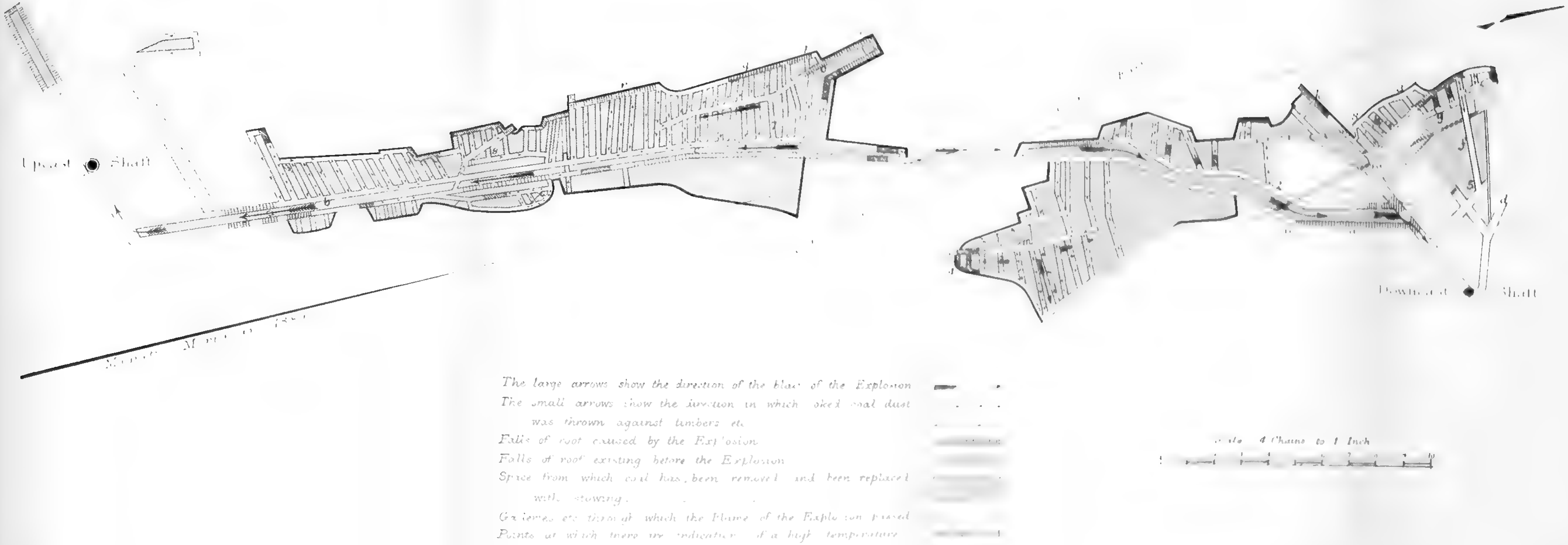
EXPLOSION





PENYGRAIG COLLIERY EXPLOSION.

10th December 1880



given off at a more or less uniform rate along the face of the solid coal. From observations made at the time I estimated that the air-current, which would receive a certain proportion of gas from each working place through which it passed in succession, would, on leaving the last working place nearest the upcast shaft, always contain rather more than 2 per cent. of fire-damp; and I have no doubt whatever that this *latent* fire-damp, acting in conjunction with the coal-dust, was a most important factor in promoting and intensifying the explosion.

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not be allowed to pass away without some record of his career in our obituary notices.

Dean Stanley was born at Alderley in Cheshire, on December 13th, 1815. His father, a brother of the first Lord Stanley of Alderley, and then Rector of the parish, was afterwards better known as the energetic, liberal, and enlightened Bishop of Norwich, who among many other accomplishments, was an enthusiastic ornithologist, the author of a still favourite book, the "Familiar History of Birds," and for many years President of the Linnean Society. The future Dean, though he did not inherit his father's taste for science, always took interest in and welcomed its progress. This spirit, which pervaded all his writings and conduct, may be illustrated by the following characteristic passage from his sermon on Sir Charles Lyell, preached in Westminster Abbey in 1875, "The tranquil triumph of geology," he says, "once thought so dangerous, now so quietly accepted by the church, no less than by the world, is one more proof of the groundlessness of theological panics in the face of the advances of scientific discovery." He was educated under Dr. Arnold, at Rugby, and commenced a brilliant career at Oxford by obtaining a scholarship at Balliol, and shortly after the Newdigate Prize for his English poem, "The Gipsies." After gaining the Ireland scholarship, he took a first class in classics in 1837, gained the Chancellor's prize for the Latin Essay in 1839, won the English Essay and the Ellerton Theological Prizes, and was elected a Fellow of University College in 1840, where for twelve years he was tutor. He did good service in the cause of university reform, by acting as Secretary to the Oxford University Commission of 1850–52, and was about the same time made a Canon of Canterbury Cathedral. In 1853, he returned to Oxford as Regius Professor of Ecclesiastical History, and Canon of Christchurch, which office he held until his appointment in 1863 to the Deanery of Westminster, a position which he held up to the time of his death, and which he filled in such a manner as to have given the Abbey a place in the history of the religious thought and feeling of the nation, which it had never taken before. His marriage about the same time with Lady Augusta Bruce, contributed to make the Deanery from that time forth a centre of all that was intellectual, cultivated, and refined in English society, and at the same time a place where persons of any distinction, whatever their class, creed, or opinions, were equally welcome, and could meet on equal terms. He was elected F.R.S. in 1863, and in 1875 was chosen Lord Rector of the University of St. Andrew's. The first published work by which Dean Stanley was generally known, was his "Life and Letters of Dr. Arnold"—a work generally admitted to be almost without a rival in modern biography, both for the interest of its subject and the accomplished grace of its treatment. This has been followed by "Lectures on the Jewish

Church," in three volumes, "Lectures on the Eastern Church," numerous sermons and essays, "Historical Memorials of Canterbury and of Westminster," and "Sinai and Palestine," which contains the most vividly picturesque topographical, and historical descriptions of those countries to be found in the language, based on observations made in a journey to the East in 1852–53. The series of sermons which he deemed it part of his duty to preach in the Abbey on all occasions of national and historical interest, will, it is hoped, shortly be published in a collected form.

The wide-spread and enduring popularity of these numerous works is due not only to the intrinsic interest of the subjects chosen, and the brilliance, grace, and charm of the language in which they are written, but also in great measure to the spirit with which they are animated—a spirit which though it can be discerned through all he wrote, could only be fully appreciated by those who knew him personally, for his were, in the words of his successor to the Deanery, "the courage which never looked behind to see who followed as he sprang forward in the defence of anyone whom he deemed unfairly overborne by intolerance or injustice, the inexhaustible fund of tenderness that never failed his friends in the hour of distress, the indescribable gifts and graces that defied analysis which won him not only the undying love of those that knew him, but the hearts of multitudes who never saw him, the imagination, the genius, and the knowledge that cast such a flood of light on the persons, the places, the events, the scenes of so many stages of human history, the ardour that threw itself so keenly into all the interests of the present and all the problems of the future, the purity of heart that made men feel that they could not think of evil in his presence, the largeness of heart that tried so earnestly 'to knit the knots of peace and love throughout all Christian lands,' and the voice that year after year pleaded so eagerly for 'whatsoever things are lovely, whatsoever things are pure, whatsoever things are of good report.'"

Adams (A. Leith), F.R.S. Monograph on the British Fossil Elephants. 4to. *London* 1881. The Author.

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CONTENTS (*continued*).

GOVERNMENT GRANT OF £1000.

A Meeting of the Government-Grant Committee will be held in February, 1882. It is requested that applications to be considered at that Meeting be forwarded to the Secretaries of the Royal Society, Burlington House, before the 31st December, 1881.

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December 8, 1881.

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extracting hairs for examination I took them from a considerable breadth of margin, and as the proportion of the hairs examined which showed any change or evidence of organisms was small, it is probable that these are present only in a narrow zone, and that after a hair is once attacked development takes place rapidly and the hair soon falls.

It may be well to divide the statements made in this paper into two heads; those which relate to ascertained facts, and those which relate to a theory of the causation of alopecia areata, which I believe is sustained by these facts:—

1. The facts are that minute bodies of definite and fixed shape and size are found in and on the hairs in alopecia areata. These bodies are distinct from the granular elements present in hairs, and are neither oily particles nor crystals. They are of the size and shape, and have the refractive qualities of bacteria. When present in small numbers on the shaft the hair is entire, whilst within some hairs much affected by the disease they were found in great numbers.

2. The theory is that these bodies are bacteria, and that the disappearance of the hair is due to a breaking up of the hair shaft by the multiplication in it of the organisms.

As I believe it is desirable to give to definite objects like those which I have described a name which will mark their association with the theory I have founded on them, and as I am myself satisfied as to their nature, I suggest the term *Bacterium decalvans* as a convenient designation.

DESCRIPTION OF PLATE 3.

Figure 1. Case of S. B. A small group of organisms on the shaft of the hair, under the cuticle. Others are seen scattered in a granular mass which is adherent to the hair.
(Camera drawing.) × 600.

Figure 2. Case of I. F. Organisms between the root-sheath and the shaft of the hair near the root. (Drawn by Mr. Noble Smith.)
× about 470.

Figure 3. Organisms from the group shown in fig. 2, more highly magnified.
(Camera drawing.) × 560.

Figure 4. The hair shown in fig. 2, the focus being now in the axis of the hair. The position of the organisms is indicated by the dark shading.

Figure 5. The hair shown in fig. 2 when the focus is carried down to the under surface, the position of the organisms being again indicated by the dark shading.

Figure 6. Case of S. B. In a part of the hair from which the substance of the hair-shaft has disappeared and the cuticle left empty, organisms are seen lying on the internal surface of the cuticle.
(Camera drawing.) × 880.

Figure 7. Case of N. S. Organisms on the shaft and be[illegible]th the cuticle.
(Camera drawing.)

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December 22, 1881.

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Transactions (*continued*).

Turin:—R. Accademia delle Scienze. Atti. Vol. XVII. Disp. 1. 8vo. *Torino.* The Academy.

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